Regional Appropriation of University-Based Knowledge and Technology for Economic Development

By: David B. Audretsch, Dennis P. Leyden, Albert N. Link

Audretsch, D. B., Leyden, D. P., & Link, A. N. (2013). Regional appropriation of university-based knowledge and technology for economic development. *Economic Development Quarterly*, 27(1), pp. 56-61.

Made available courtesy of Sage Publications: http://dx.doi.org/10.1177/0891242412472536

*****© The Authors. Reprinted with permission. No further reproduction is authorized without written permission from the authors & Sage Publication. This version of the document is not the version of record. Figures and/or pictures may be missing from this format of the document. *****

Abstract:

Economic development practitioners and scholars recognize the link between universities and regional economic development. It is predicated on the spillover of knowledge from universities to commercialization. The literature has focused on the supply side, which involves university research and technology transfer mechanisms. We examine the role played by the demand for university-based knowledge and university-developed technology. We identify links between businesses and the university as a key conduit facilitating the spillover of knowledge using data on the Department of Energy's Small Business Innovation Research (SBIR) program. We provide supply-side evidence on university research relationships and how the use of knowledge and technologies that flow from a university affect economic growth. We identify the role that SBIR-funded businesses play in the spillover of knowledge from the creating organization to where that knowledge is used and commercialized. Our results suggest that knowledge is systematically transmitted through university-related research.

Keywords: economic development | entrepreneurship | innovation | licensing | SBIR program | university research

Article:

Introduction

Economic development practitioners and scholars have long recognized that the link between universities and regional economic development is predicated on the spillover of knowledge from the university to commercialization, which ultimately can drive regional economic development. However, there is considerably less understanding of how and why university-generated knowledge spills over to generate economic growth and development of regions. Scholarly writings on academic entrepreneurship are replete with analyses of the *supply* of university-based technical knowledge and university-developed technologies. Audretsch and Stephan (1996), Zucker and Darby (1997), and Zucker, Darby, and Brewer (1998) documented the importance of the transfer of university-based technical knowledge to the growth of the U.S. biotechnology industry, and Bozeman, Hardin, and Link (2008) reached similar conclusions from their study of regional development associated with the growth of nanotechnology. Phan and Siegel (2006) and Rothaermel, Agung, and Jiang (2007) documented the supply of university-developed technologies transferred to the private sector through university technology transfer and commercialization offices.

There have been few inquiries into the *demand* for technical knowledge and related technologies. The literature on university research parks suggests that firms locate in a park to gain early access to university research and graduate students (Leyden, Link, & Siegel, 2008). This was established by Link and Scott (2007) for U.S. parks and by the National Research Council (2009) for international parks. As well, there are studies of universities as research partners. Hall, Link, and Scott (2003), Bozeman et al. (2008), and Link and Wessner (2011) report the extent to which critical technical knowledge flows to businesses through university-based research partnerships.

In this article, we advance the literature on the demand for university-based knowledge and university-developed technology by describing the breadth of economic impact to businesses that have a university research relationship. Our description is based on data related to small entrepreneurial businesses that have been funded through the Department of Energy's (DOE's) Small Business Innovation Research (SBIR) program. We provide supply-side evidence on the nature of university research relationships and how the character of use of technical knowledge and technologies that flow from a university impact economic growth.

In the next section, we describe the SBIR program, and in the third section, we overview the SBIR database and our focus on DOE-funded research. In the fourth section, we present and discuss our findings. Finally, we posit an agenda for research linking regional economic development to the supply of and the demand for university-based knowledge and attendant technologies.

The SBIR Program

The SBIR program was created under the Small Business Innovation Development Act of 1982 to stimulate technological innovation, use small business to meet Federal research and development needs, foster and encourage participation by minority and disadvantaged persons in technological innovation, and increase private-sector commercialization of innovations derived from Federal research and development (R&D).[1]

Each government agency with an extramural research budget is required to set aside a portion (currently equal to 2.5%) of that budget to award to small (500 or fewer employees) U.S. businesses (at least 51% owned by U.S. citizens or lawfully admitted permanent resident aliens) in response to requests for proposals on defined topics. The structure of the SBIR program is defined by three phases: Phase I awards assist businesses as they assess the feasibility of an idea's scientific and commercial potential in response to the funding agency's objectives; currently these are 6-month awards for up to $100,000. Phase II awards assist businesses in furthering their Phase I research with an expectation that the resulting technology will be commercialized; currently these are 2-year awards for up to $1,000,000. There are no SBIR awards in Phase III; it is the period of time when the funded businesses are to move their technology from the laboratory into the market place. The business is expected to find private sector funding (e.g., from venture capitalists) during this period.

Eleven agencies participate in the SBIR program, with the Department of Defense (DoD) accounting for nearly 58% of all awards, followed by Health and Human Services' National Institutes of Health (NIH) with about 19%, and DOE with about 6% (along with the National Aeronautics and Space Administration and the National Science Foundation with similar percentages). About $2 billion per year is currently allocated to Phase I and Phase II awards, with nearly 98% accounted for by these five agencies.

The SBIR Database

As part of the SBIR program's reauthorization in 2000, Congress charged the National Research Council to undertake an evaluation study of the program. That study led to a 2005 survey of 11,214 Phase II projects funded from 1992 through 2001.

Although not receiving the largest share of funding, there are compelling reasons for focusing on DOE awards in this study. First, businesses funded through DoD have a captive audience for their resulting technology, namely, DoD itself (Link & Scott, 2009; Nelson, 1982). Thus, their behavior is not guided entirely by market pressures. Second, NIH is composed of 27 heterogeneous research institutes and centers (Link & Ruhm, 2009). Thus, businesses funded through DOE are more likely to have measurable market-based incentives for creating and commercializing new technologies, relying strategically on universities as a source of knowledge.

Table 1. Descriptive Statistics on the NRC Survey of DOE Phase II Awards, 1992-2001.

Data reduction	Number of Phase II projects
Completed Phase II projects	808
Phase II survey sample size	439
Phase II random survey sample size[a]	436
Responses to the random survey[b]	154
Response rate to the random survey	35.3%

Note. NRC = National Research Council; DoE = Department of Energy. a. The NRC surveyed a number of nonrandomly selected projects (n = 3) because they were projects that had realized significant commercialization, and the NRC wanted to emphasize success stories to Congress (National Research Council, 2008). b. To test empirically for selection bias, we estimated a model of the probability of response as a function of the number of employees involved in the surveyed project. Absent a strong theoretical foundation for why some businesses would respond to the NRC survey and others would not for a particular project, we conjecture that the greater the number of employees the greater the likelihood that the business would have available resources to respond. The estimated probit coefficient on number of employees was positive, but not statistically significant. These results are available on request.

University-Based Knowledge and Technologies

This article focuses on the demand for and supply of university-developed technologies. Of the 154 DOE-funded survey respondents (see Table 1), data were available on dimensions of university involvement, or its lack of, for 122 projects. Of these, a university was involved in Phase II research in 55 projects (45.1%).[2]

Surprisingly, there is a void in the academic literature linking the demand for and supply of university-developed technologies. Figure 1 illustrates a motivating model of that relationship: Q is the level of university inputs used by the business in its DOE-funded project, MC is the marginal cost of acquiring those inputs, and MRe is the expected marginal revenue from the results of the innovation process that use university inputs.[3] In equilibrium, the business will acquire for the SBIR-funded project Q_0 amount of university inputs, and it will use them to generate revenue defined by the rectangle $0Q_0$ and Q_0E_0.

Table 2 lists the dimensions through which university-based knowledge and related technologies are supplied, and the extent of the supply relationship is described through the percentages of use. The university-based knowledge most commonly supplied is faculty acting as consultants and/or subcontractors (61.8%), use of graduate students (52.7%), and use of university equipment/facilities (43.6%).

There are at least two interesting relationships suggested from the simple correlation of these dimensions in Table 3. One is the lack of statistical evidence of a trade-off between licensing university-developed technology (Licensed Technology) and using own technology developed at the university by a recipient of the Phase II award (Developed Technology)—the correlation coefficient is −0.074, but it is not significant.[4] Two is the positive and significant correlation between the PI being an adjunct faculty member (Adjunct PI) and the project relying on technology developed at the university (Developed Technology)—the correlation coefficient is 0.259 and it is marginally significant. This relationship is not inconsistent with the adjunct faculty member taking university technology that he/she developed out the back door rather than transferring it through a university license (Bozeman, Link, & Siegel, 2007).

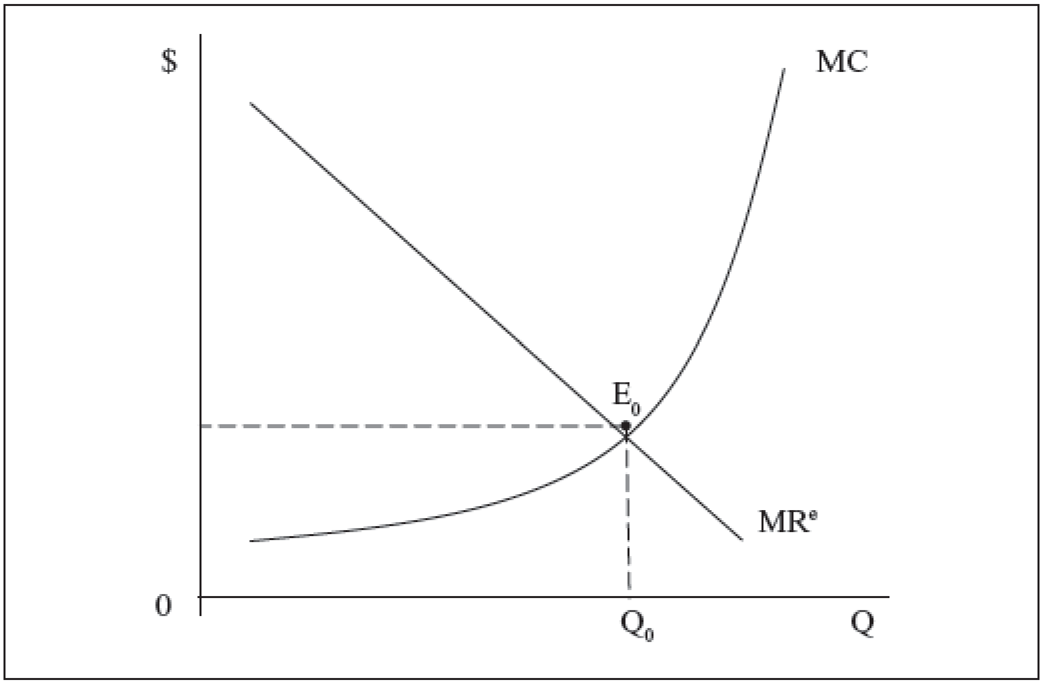

Figure 1. Demand for and supply of university-developed technologies.

Table 2. Dimensions of the Supply of University-Based Knowledge and Technology, *n* = 55.

Supply dimensions	Percentage of projects
The PI for the Phase II project was at the time of the project a faculty member at the university with which the business had a research relationship	0
The PI for the Phase II project was at the time of the project an adjunct faculty member at the university with which the business had a research relationship	9.1
Faculty or adjunct faculty worked on the Phase II project in a role other than PI	61.8
Graduate students worked on the Phase II project	52.7
University equipment or facilities were used on the Phase II project	43.6
Elements of the technology developed on the Phase II project were licensed from the university (Licensed Technology)	3.6
Elements of the technology developed on the Phase II project were developed at the university by the recipient of the Phase II award (Developed Technology)	12.7
A university was used as a subcontractor on the Phase II project	45.5

Note. PI = principal investigator; NRC = National Research Council. *Source*. NRC survey instrument.

Scholars and practitioners recognize that knowledge is the key driver of economic development. As Griliches (1979) and Romer (1986) pointed out, the impact of knowledge on economic growth and development is particularly potent because of its propensity to spill over from the organization where it is created to a different organization where it is actually used and commercialized.

The activities identified in Table 4 serve as conduits for the spillover of knowledge created in one organizational context to its actual application and development in a different organizational context. Some emanate from university-generated knowledge, whereas others emanate from businesses. The actual transmission mechanisms include licensing agreements, the sale of a business, and the sale of technology, mergers, joint venture agreement, marketing agreement, manufacturing agreement, R&D agreement, and customer alliance. Each involves a flow of knowledge across organizational contexts that can result in the generation of innovations, growth, and jobs.

Table 4 is interpreted as follows.[5] For example, 16.7% of the 55 projects involving a university have finalized licensing agreements with other U.S. companies as a result of technology developed during the SBIR-funded project. Similarly, 14.9% of the 67 projects for which there was no university involvement have finalized licensing agreements with other U.S. companies as a result of technology developed during the SBIR-funded project.

The data suggest that, regardless of the type of technology-related agreements and with whom they are forged, agreements in general are more likely to occur when a university is involved in the underlying Phase II research. This suggests that knowledge spillovers, and ultimately economic development, tend to be greater for Phase II projects that involve a university research relationship. However, this observation should be interpreted with caution. First, the data in the table do not take into account the dimensions of interaction with the university—see Table 2. Second, the Phase II projects were funded over the period 1992 to 2001, and the amount of the funding varied by project even though all projects were Phase II projects. Thus, a business funded more recently would have had less time to develop/finalize technology-related agreements than would a business funded at the beginning of the sampling period. Also, to the extent that the amount of funding is associated with the scope of the Phase II research, one might expect that those greater funded projects would also have greater opportunities to develop agreements. Unfortunately, data are not available to disentangle these possibilities.

Table 3. Correlation Matrix of Dimensions of the Supply of University-Based Knowledge and Technology, *n* = 55.

	Faculty PI	Adjunct PI	Faculty consultant	Graduate student	Equipment	Licensed technology	Developed technology	Subcontractor
Faculty PI	—	—						
Adjunct PI	—	1.0						
Faculty consultant	—	−0.272*	1.0					
Graduate	—	0.005	1.0					

student	0.173							
Equipment	—	0.232**	0.088	0.319*	1.0			
Licensed technology	—	−0.061	−0.247**	−0.205	−0.171	1.0		
Developed technology	—	0.259**	−0.149	−0.076	0.104	−0.074	1.0	
Subcontractor	—	−0.162	−0.109	0.206	0.301**	0.018	0.199	1.0

*Significant at the .05 level. **Significant at the .10 level.

Table 4. Business Activity With Other Businesses or Investors Involving the Technology Developed During the Phase II Project, *n* = 122.

	U.S. businesses/investors		Foreign businesses/investors	
Activity	Finalized agreements	Ongoing negotiations	Finalized agreements	Ongoing negotiations
Licensing agreement(s)	16.7%/14.9%	21.4%/10.4%	9.5%/3.0%	9.5%/6.0%
Sale of the business	0%/1.5%	2.4%/0%	2.4%/0%	0%/1.5%
Partial sale of the business	4.7%/1.5%	2.4%/0%	0%/0%	2.4%/1.5%
Sale of technology rights	7.1%/4.5%	7.1%/6.0%	0%/1.5%	2/4%/3.0%
Company merger	0%/0%	0%/1.5%	0%/0%	0%/1.5%
Joint venture agreement	0%/4.5%	7.1%/6.0%	0%/0%	0%/3.0%
Marketing agreement(s)	9.5%/10.4%	4.8%/7.5%	9.5%/9.0%	2.4%/1.5%
Manufacturing agreement(s)	0%/9.0%	7.1%/4.5%	0%/1.5%	21.6%/3.0%
R&D agreement(s)	7.1%/4.5%	11.9%/9.0%	2.4%/1.5%	7.1%/3.0%
Customer alliance(s)	9.5%/7.5%	21.4%/7.5%	2.4%/6.0%	7.1%/3.0%

Note. Values presented are percentage *with* university relationship/percentage *without* university relationship.

To investigate more formally the relationship between economic development activity and involvement with a university, we estimated:

$ACTIVITY = f(UNIV, \mathbf{X})$, (1)

where *ACTIVITY* represents business involvement in any technology-related activity defined by Table 4; *UNIV* represents university involvement in the Phase II research, in general and by type of involvement; and **X** is a vector of control variables.

ACTIVITY is measured in two ways: first as the sum of all finalized activity agreements with other U.S. businesses or investors—$ACTIVITY_{U.S.}$ —and second as the sum of all finalized agreements with other foreign businesses or investors—$ACTIVITY_{Foreign}$.[6,7]

UNIV is measured in nine ways. *UNIV* = 1 if a university was involved in any way with the Phase II research, and 0 otherwise. The other eight ways correspond to the eight dimensions through which university-based technical knowledge or technology is supplied (Table 2). Our discussion focuses on two of the eight ways, although all were considered. $UNIV_{License}$ = 1 if elements of the technology developed on the Phase II project were licensed from the university, and 0 otherwise; and $UNIV_{Develop}$ = 1 if elements of the technology developed on the Phase II project were developed at the university by the recipient of the Phase II award, and 0 otherwise.

Also held constant in Equation (1) are the age of the Phase II project, *AGE*, measured as the number of years between receipt of the Phase II funding and 2005, and the dollar amount of the Phase II award, ln*AWARD*.[8]

Descriptive statistics are in Table 5, and the regression results are in Table 6. The results suggest that university involvement in a DOE SBIR-funded project does not affect business activities with other businesses or investors, be they domestic of foreign. The coefficients on *UNIV* in columns (1) and (3) are positive but are not significant at a conventional level. However, when the elements of the technology developed on the Phase II project were licensed from the university, the economic development impact (Table 4) is positive. The coefficients on $UNIV_{License}$ in columns (2) and (4) are positive and significant at the .05 level. Such was not the case for own-developed university-based technologies.

Table 5. Descriptive Statistics on the Variables Used to Estimate Equation (1), *n* = 109a.

Variable	Mean	Standard Error	Range
$ACTIVITY_{U.S.}$	0.569	0.946	0-4
$ACTIVITY_{Foreign}$	0.239	0.639	0-5
$UNIV_{License}$	0.036	0.187	0/1
$UNIV_{Develop}$	0.125	0.334	0/1
AGE	7.731	2.742	4-13
ln*AWARD*	13.416	0.181	12.71-13.71

a. Activity information was available for 109 projects.

Also shown is that the size of the SBIR award does have an impact on U.S. agreements but not on foreign agreements. Larger awards, which possibly are associated with research that is broader in scope, contribute in a relatively greater amount to domestic economic development spillovers associated with the SBIR program.

Table 6. Negative Binominal Regression Results of Equation (1), *n* = 109.

	$ACTIVITY_{U.S.}$	$ACTIVITY_{Foreign}$

Independent variable	(1)	(2)	(3)	(4)
UNIV	0.0006 (0.321)	—	0.198 (0.483)	—
UNIVLicense	—	1.491** (2.412)	—	1.983** (0.583)
UNIVDevelop	—	1.491 (0.640)	—	−0.478 (1.148)
AGE	0.289* (0.083)	0.202 (0.143)	0.174 (0.119)	0.080 (0.117)
ln*AWARD*	3.991* (1.426)	4.994** (2.412)	2.665 (2.045)	0.191 (1.471)
Intercept	−56.528* (19.629)	−69.422** (33.230)	−38.695 (28.111)	−4.495 (20.103)
Log likelihood	−83.413	−26.761	−64.268	−22.993
χ^2 (*df*)	99.145	32.107	139.98	37.453

Note. Standard errors in parentheses. The results reported in this table are unchanged under a tobit specification of the model. *Significant at .01 level. **Significant at .05 level.***Significant at .10 level.

Conclusions

Practitioners and scholars are unanimous in their consensus that knowledge is the driving force that is key to the growth and employment creation inherent in the process of economic development. There is less consensus about where that knowledge comes from. For example, Nobel laureate Robert Solow (1957) has been attributed with observing that knowledge falls like manna from heaven, suggesting a role for stochastic processes. The implications for public policy were perhaps as startling for theology as they were for traditional economic institutions. New growth theory, pioneered by Paul Romer (1986), shifted the focus to the supply side by recognizing the role that institutions, such as universities, play in investing in knowledge. Rather, than manna from heaven, Romer argued that knowledge systematically spills over from a neighbor, if the recipient is located within close geographic proximity to the source of that knowledge. By contrast, in this article we show that the demand for knowledge also plays a key role.

By analyzing small businesses funded by the SBIR program and their technological activities with other business entities, we identified the key role that such small businesses play in providing a conduit for the spillover of knowledge from the organization in which knowledge is created to a different organization where that knowledge is used and commercialized. Our empirical findings suggest that those SBIR-funded projects are involved in a greater number of spillover conduits when the technology is licensed from a university and the university technology transfer office is directly involved. In addition, knowledge spillovers appear to be greater for those projects with a higher level of funding. These results suggest that knowledge does not merely fall like manna from heaven or automatically spill over. Rather, knowledge spillovers do not occur automatically, but are transmitted by conduits, and in particular, Phase II projects involved with university research.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Notes

1. See National Research Council (2008) and Link and Scott (2010, 2012).

2. We tested for selection bias and rejected it as being an issue.

3. Because innovation is an uncertain process, university inputs are assumed both to increase the probability that the innovation process results in a marketable product and to increase the value of that resulting product; hence, expected marginal revenue.

4. For a discussion of the "make versus buy" decision, see Link, Tassey, and Zmud (1983).

5. Note, 55 projects involved with a university plus 67 projects not involved with a university equals 122 projects.

6. If a respondent reported "no" for all of the 10 U.S. activities listed in Table 4, $ACTIVITY_{U.S.}$ equals 0. However, if the respondent reported "yes" for a finalized R&D agreement and "yes" for an ongoing negotiation for a manufacturing agreement, $ACTIVITY_{U.S.}$ equals 2.

7. Absent a definition of "ongoing negotiations" in the database, there is less uncertainty (and less noise in the *ACTIVITY* variables) by using only finalized agreements in our analysis.

8. The award amount is logarithmic to account for nonlinearity.

References

Audretsch, D. B., & Stephan, P. E. (1996). Company-scientist locational links: The case of biotechnology. *American Economic Review*, *86*, 641-652.

Bozeman, B., Hardin, J., & Link, A. N. (2008). Barriers to the diffusion of nanotechnology. *Economics of Innovation and New Technology*, *17*, 751-763.

Bozeman, B., Link, A. N., & Siegel, D. S. (2007). An empirical analysis of the propensity of academics to engage in informal university technology transfer. *Industrial and Corporate Change*, *16*, 641-655.

Griliches, Z. (1979). Issues in assessing the contribution of research and development to productivity growth. *Bell Journal of Economics*, *10*, 92-116.

Hall, B. H., Link, A. N., & Scott, J. T. (2003). Universities as research partners. *Review of Economics and Statistics*, *85*, 485-491.

Leyden, D. P., Link, A. N., & Siegel, D. S. (2008). A theoretical and empirical analysis of the decision to locate on a university research park. *IEEE Transactions on Engineering Management, 55,* 23-28.

Link, A. N., & Ruhm, C. J. (2009). Bringing science to market: Commercializing from NIH SBIR Awards. *Economics of Innovation and New Technology*, *18,* 381-402.

Link, A. N., & Scott, J. T. (2007). The economics of university research parks. *Oxford Review of Economic Policy*, *23*, 661-674.

Link, A. N., & Scott, J. T. (2009). Private investor participation and commercialization rates for government-sponsored research and development: Would a prediction market improve the performance of the SBIR program? *Economica*, *76*, 264-281.

Link, A. N., & Scott, J. T. (2010). Government as entrepreneur: Evaluating the commercialization success of SBIR projects. *Research Policy*, *39*, 589-601.

Link, A. N., & Scott, J. T. (2012). *Employment growth from public support of innovation in small firms*. Kalamazoo, MI: W. E. Upjohn Institute.

Link, A. N., Tassey, G., & Zmud, R. W. (1983). The induce versus purchase decision: An empirical analysis of industrial R&D. *Decision Sciences*, *14*, 46-61.

Link, A. N., & Wessner, C. W. (2011). Universities as research partners: Entrepreneurial explorations and exploitations. In D. Audretsch (Ed.), *Handbook of research on innovation and entrepreneurship* (pp. 290-299). London, England: Edward Elgar.

National Research Council. (2008). *An assessment of Small Business Innovation Research Program at the Department of Energy* (C. W. Wessner, ed.). Washington, DC: National Academies Press.

National Research Council. (2009). Understanding research, science and technology parks: Global best practices (C. W. Wessner, ed.). Washington, DC: National Academies Press.

Nelson, R. R. (1982). Government stimulus of technological progress: Lessons from American history. In R. R. Nelson (Ed.), *Government and technical progress* (pp. 451-482). New York, NY: Pergamon.

Phan, P. H., & Siegel, D. S. (2006). The effectiveness of university technology transfer. *Foundations and Trends in Entrepreneurship, 2,* 77-144.

Romer, P. (1986). Increasing returns and long-run growth. *Journal of Political Economy*, *94*, 1002-1037.

Rothaermel, F. T., Agung, S. D., & Jiang, L. (2007). University entrepreneurship: A taxonomy of the literature. *Industrial and Corporate Change*, *16*, 691-791.

Solow, R. F. (1957). Technical change and the aggregate production function. *Review of Economics and Statistics*, *39*, 312-320.

Zucker, L. G., & Darby, M. R. (1997). Present at the biotechnology revolution: Transformation of technical identity for a large number of incumbent pharmaceutical firms. *Research Policy*, *26*, 429-446.

Zucker, L. G., Darby, M. R., & Brewer, M. B. (1998). Intellectual human capital and the birth of U.S. biotechnology enterprises. *American Economic Review*, *88*, 290-306.

Author Biographies

David B. Audretsch is Professor of Economics and Director of the Institute of Development Strategies at Indiana University.

Dennis P. Leyden is Associate Professor of Economics at the University of North Carolina at Greensboro.

Albert N. Link is Professor of Economics at the University of North Carolina at Greensboro and the U.S. Representative to the United National Economic Commission for Europe.