



ilis

Local Innovation Systems Project

PHASE I

UNIVERSITIES, INNOVATION, AND THE COMPETITIVENESS OF LOCAL ECONOMIES
A Summary Report from the Local Innovation Systems Project-Phase I

Richard K. Lester
Industrial Performance Center
Massachusetts Institute of Technology

**Universities, Innovation,
and the
Competitiveness
of Local Economies**

**A Summary Report from the
Local Innovation Systems Project – Phase I**

Richard K. Lester
Industrial Performance Center
Massachusetts Institute of Technology

13 December 2005

MIT Industrial Performance Center Working Paper 05-010

The LIS Project Team

United States

Prof. Richard K. Lester *IPC* (**Project Director**)

Prof. Danny Breznitz *Georgia Institute of Technology*

Shiri M. Breznitz *IPC*

Prof. Alok Chakrabarti *New Jersey Institute of Technology*

Dr. Jean-Jacques Degroof *IPC*

Wei Gao *IPC*

Dr. Sachi Hatakenaka *IPC*

Carlos Martínez-Vela *IPC*

Prof. Michael J. Piore *IPC*

Prof. Sean Safford *University of Chicago*

Dr. Smita Srinivas *Harvard University*

Finland

Prof. Markku Sotarauta *Sente, University of Tampere*

Kati-Jasmin Kosonen *Sente, University of Tampere*

Kimmo Viljamaa *Sente, University of Tampere*

Prof. Eila Järvenpää *Helsinki University of Technology*

Dr. Stina Immonen *Helsinki University of Technology*

Katja Lahenius *Helsinki University of Technology*

Juha Nummi *Helsinki University of Technology*

Norway

Dr. Martin Gjelsvik *Rogaland Research Institute*

Petter Westnes *Rogaland Research Institute*

United Kingdom

Prof. Alan Hughes *Center for Business Research, University of Cambridge*

Dr. Andy Cosh *Center for Business Research, University of Cambridge*

Maria Corte-Real *Center for Business Research, University of Cambridge*

Dr. Celine Druilhe *Diagnostics for the Real World Ltd.*

EXECUTIVE SUMMARY

This report shows how universities can support local economic development through their contributions to local industrial innovation processes.

The vigor and dynamism of local economies depends on the ability of local firms to adapt to changing markets and technologies by continually introducing commercially viable products, services, and production processes – that is, by innovating successfully. Not all local economies adapt with equal success. The outcome depends on the capabilities of local firms to take up new technological and market knowledge and to apply it effectively. This report focuses on the contributions made by local universities to those capabilities.

The findings draw on studies of innovation-enabled industrial change in twenty-two locations in six countries. These studies were carried out in the Local Innovation Systems Project between 2002 and 2005. The locations include both high-tech and economically less favored regions. The sectors include both mature and new industries. Some of the locations are home to first-tier universities, some to second-tier universities, and some to no universities at all.

The evidence shows that universities contribute to local innovation processes in a variety of ways. At present the major focus is on technology transfer. Many universities are seeking to exploit their laboratory discoveries by patenting and licensing intellectual property to local firms. But often this is not the most important contribution. In addition to their own discoveries, universities can help to attract new human, knowledge, and financial resources from elsewhere. They can help to adapt knowledge originating elsewhere to local conditions. They can help to integrate previously separate areas of technological activity. They can help to unlock and redirect knowledge that is already present in the region but not being put to productive use.

Very often the university's most important contribution is education. Another important indirect role is to serve as a public space for ongoing local conversations about the future direction of technologies and markets. The importance of the public space role of the university and its contribution to local innovation performance is often underestimated.

A key finding is that the university role in local innovation processes depends on what kind of industrial transformation is occurring in the local economy. New industry formation, industry transplantation, industry diversification, and industry upgrading are each associated with a different pattern of technology take-up and with a different set of university contributions.

These findings strongly suggest that the 'one-size-fits-all' approach to economic development pursued by so many universities, with its focus on patenting, licensing, and new business formation, should be replaced with a more comprehensive, more differentiated view of the university role. Universities need a stronger awareness of the pathways along which local industries are developing and the innovation processes that are associated with those pathways. They should seek to align their own contributions with what is actually happening in the local economy. This strategic approach to local economic development is fully compatible with the pursuit of excellence in the university's traditional primary missions of education and research.

Preface

This report summarizes research carried out during the first phase of the Local Innovation Systems (LIS) Project. This international collaboration, based at the MIT Industrial Performance Center, brings together researchers in engineering, management, and the social sciences from universities in five countries. The LIS Project is about – and itself exemplifies – a phenomenon neatly captured by one of our MIT colleagues: knowledge is global, but learning is local. * Universities, whose very existence as institutions of learning and knowledge creation rests on this apparent contradiction, now find themselves on the front lines of a larger struggle to square the circle, as economic activity becomes both increasingly globalized and increasingly knowledge-based. As local communities throughout the world worry about their economic survival in the rapidly changing and increasingly open world economy, their attention naturally turns to local universities, sources of the two most valuable assets in this economy: educated, skilled people, and new ideas. How should universities respond to these new challenges? What should we expect of them? What should they expect of themselves? We have been able to explore these important questions in the stimulating environment of the cross-disciplinary, cross-national LIS Project thanks to the generosity of several sponsors. The financial support provided by these sponsors has also helped four of the doctoral students working on the project to complete their dissertations and another seven to make substantial progress towards completion. We are especially grateful to Tekes (the National Technology Agency of Finland), the Cambridge-MIT Institute, and the Research Council of Norway for their generous support of the international components of the project, and to the Alfred P. Sloan Foundation for helping to support the U.S.-based research. We are also grateful to the National Science Foundation for its support of aspects of the U.S.-Finnish cooperation. Additional support was provided by the University of Tokyo in the early stages of this project. Finally, special thanks go to the CMI Program on Regional Innovation and the Office of the Vice President for Research at MIT for helping to underwrite the First International Conference on Local Innovation Systems, held at MIT on 13 December 2005, at which this report was presented and discussed.

* Rosalind Williams, *Retooling: A Historian Confronts Technological Change*, MIT Press, Cambridge, 2002.

“The university today finds itself in a quite novel position in society. It faces a new role with few precedents to fall back on . . . We are just now perceiving that the university's invisible product, knowledge, may be the most powerful single element in our culture, affecting the rise and fall of professions and even of social classes, of regions, and even of nations.”

-- Clark Kerr, *The Uses of the University* (1963)

Introduction

This project addresses a fundamental question confronting the citizens of all advanced societies: How can local communities, with few economic resources on which to draw, prosper in the rapidly changing and increasingly open global economy? What can these communities do to improve their economic prospects in the short and long run?

For more than a decade, a roiling debate about the consequences of globalization has swept across the industrialized world. The great globalization debate has focused on the role of national governments as instruments for promoting the benefits of globalization or, more often, for ameliorating its negative impacts. National governments have found themselves in the firing line as anxious constituents seek protection against what they see as the depredations of global corporations, global capital flows, and the integration into the global economy of huge pools of low-wage labor in the developing world.

In retrospect, the predictions of some early analysts of globalization that national governments would become essentially irrelevant, powerless to set or enforce the rules and at the mercy of rootless corporations moving productive assets across national borders at will, have turned out to be exaggerated. It is much too soon to write the obituary of national governments as players in the global economy. Despite some encroachments on governmental authority, national borders still do matter in economic affairs.

But from the perspective of local communities the sense of vulnerability to the forces of globalization is acute, and probably also more warranted. From the local perspective the rules of the game are indeed mostly set elsewhere. Local communities have fewer resources

available to cope with the impacts of globalization. Indeed, local leadership has itself often been eroded as the traditional pillars of the local economy – banks, manufacturing firms, law firms, accountants, retailers, and others – have been acquired or displaced by large national or multinational organizations with no particular interest in or commitment to the community. For many local communities, the notion of a ‘borderless world’ is uncomfortably close to the truth; certainly these communities have only limited ability to shield themselves from the turbulence of global economic forces.

But local communities are not totally without recourse. Much of the hard work needed to cope with the challenges of globalization – building infrastructure, improving educational performance, strengthening cooperation between public and private institutions – is often better undertaken at the local level than by centralized directive. In this project we focus on one such response: *strengthening local capabilities for innovation*. By ‘capabilities for innovation’, we mean the ability to conceive, develop, and/or produce new products and services, to deploy new production processes, and to improve on those that already exist. The ability of the firms comprising a local economy to adapt to new market and technological opportunities through innovation is the key to sustainable growth and prosperity at the local level. The processes and outcomes of innovation are essential for productivity growth and for sustaining and improving wage rates, and are themselves associated with attractive, well-paying jobs. The links between innovation, productivity growth and prosperity are increasingly well recognized around the world.

To date, most policy initiatives directed towards improving innovation performance have been taken by national governments. But there is increasing attention to this issue at the regional and local levels too.¹ Local community leaders throughout the advanced industrialized world would surely agree with the view recently expressed by one official about the U.S. economy as a whole: “America must never compete in the battle to pay their workers least, and it will take sustained innovation to ensure that we don’t have to.”²

¹ See Roger Geiger and Creso Sa, “Beyond Technology Transfer: U.S. State Policies to Harness University Research for Economic Development”, *Minerva* (2005) 43, 1-21.

² Bruce Mehlman, Assistant Secretary of Technology Policy, U.S. Department of Commerce, in testimony before the House of Representatives Committee on Small Business, June 18, 2003, at http://www.technology.gov/Testimony/BPM_030618.htm.

Local innovative capabilities are themselves subject to the pressures of globalization, however. Even regions with significant concentrations of innovative activity today cannot assume that they will be able to hold onto them indefinitely. The range of possibilities is bracketed by two limiting scenarios. At one end of the spectrum, local companies, recognizing the importance to their own innovation processes of tapping into the global network of knowledge and ideas, reach progressively farther afield to do so, and eventually relocate these activities and perhaps ultimately all of their operations out of the region altogether. At the other end of the spectrum, local companies seek to boost their innovation performance by strengthening their ties with other local firms and with local public research and educational institutions. In this scenario the local economy emerges as a center of new knowledge creation and application, attracting firms from elsewhere, and stimulating the formation of new local businesses.

The broad goal of the Local Innovation Systems project is to study the range of possible outcomes delimited by these two scenarios. We seek to examine the consequences of the different outcomes for local economic development, and to gain insight into the actions, strategies and policies at the local level that are associated with each type of outcome. Ultimately we seek to develop actionable recommendations to local communities directed towards the strengthening of local capabilities for innovation.

Universities as ‘engines of innovation’

As local communities focus on the importance of innovation and an educated local workforce to their long-term prosperity, their attention has naturally turned to the contributions of local universities. These institutions are a primary source of the most valuable assets in the knowledge economy: highly educated people, and new ideas. The presence of universities may also attract other key economic resources to the region, including firms and educated individuals who may want to locate close by, as well as financiers, entrepreneurs and others seeking to exploit new business opportunities emanating

from the campus. And one of the most appealing features of universities from a local perspective is, of course, that – unlike so many other participants in the local economy – they are immobile. A university is necessarily committed to its region for the long term.

Throughout the world, governments – national, regional and local – are seeking ways to strengthen the role of universities as agents of local and regional economic development. In the United States a significant milestone was the passage of the federal Bayh-Dole Act of 1980, intended to promote the transfer of university-developed technology to industry. Later federal initiatives included the National Science Foundation’s Science and Technology Centers and Engineering Research Centers, both of which made important tranches of government research funding for universities contingent on industry participation. More recently state governments have become increasingly active in pressing the public universities within their jurisdictions to contribute to local economic development.

At the same time, companies have been looking more closely at university laboratories as contributors to their research and product development activities. Corporate interest has been stimulated by the growing commercial relevance of university research in important fields like biopharmaceuticals, nanotechnology, and bioengineering. Many businesses, too, have been cutting back on in-house R&D and increasing their reliance on external sources of knowledge and technology as a way of reducing the costs and risks of research. In the U.S., industry funding for academic research has grown faster than any other funding source in recent decades, although it still accounts for less than 7% of total academic research funding (compared with 58% from the Federal government), and less than 2% of total industry expenditures on R&D.³

For university administrators, if not for all campus residents, the new focus on what is sometimes referred to as the ‘third stream’ mission of economic growth (to differentiate it from the traditional missions of education and research) has generally been a welcome development, in part because of its promise of new revenues at a time when traditional revenue sources are under increasing pressure. And as the gap between academic laboratories and the marketplace has shrunk, universities, teaching hospitals, and other

³ National Science Board, *Science and Technology Indicators – 2004*, Appendix Table 4-4.

academic units have become more adept at the commercial exploitation of academic research.

But working ties to the operating sectors of the economy are not central to the internal design of the university as an institution, and as universities open themselves up to the marketplace for knowledge and ideas to a greater degree than in the past, confusion over mission has been common. On some campuses the new emphasis on industry partnerships has sparked controversy. How can universities, already financially stressed, accommodate the new mission of economic development without undermining their traditional commitment to education and basic research? How to manage the conflicts of commitment and conflicts of interest that confront faculty, administrators, and others in the economically engaged university? Will the principle of academic freedom be subsumed by the imperatives of the marketplace? Such questions are debated, more or less vigorously depending on the campus. But the underlying trend towards greater economic engagement is clear.

The ‘Standard Model’

The rising interest in the university’s economic development role has been fueled by high-profile examples of successful regional economies in which the university contribution is easily identified, such as Silicon Valley, the Boston area, and the region around Cambridge in the UK. Less widely publicized, though certainly well known to most university administrators, are cases of ‘blockbuster’ licenses on university developed and patented technology.⁴ Both kinds of success have helped to promote what has now become a standard view of the university’s economic role, centering on technology transfer. The technology transfer model starts with discoveries by university researchers in their laboratories, and proceeds to disclosure by the inventors, patenting by the university or the inventor, and ultimately licensing of the technology, frequently to startup or early stage technology-based enterprises founded by the inventors themselves.

⁴ These include the Cohen and Boyer gene splicing patent (Stanford University), the chemotherapy drug Taxol (Florida State University), and the anti-clotting medication Warfarin (University of Wisconsin).

The overall economic significance of this model, as well as its promise in particular situations, has often been exaggerated. Part of the problem is the failure to recognize that the best-known success stories are atypical. The university origins of enormously successful companies like Cisco, Google, and Yahoo (all three of which grew out of Stanford University research and two of which took Stanford licenses) are well known. Less often noted is the fact that new business formation around university science and technology is a very small fraction – probably no more than 2-3% – of the total rate of new business starts in the U.S.⁵

The same is true of patenting. Even in the U.S., where patenting by universities is most common, it is only a minor contributor to the overall stock of patented knowledge. About 3700 patents were granted to U.S. universities in 2001, out of a total of about 150,000 U.S. patents issuing in that year. Moreover, even the most prolific patenting universities are not particularly active by corporate standards.⁶

The probability that universities themselves will derive significant financial benefits from their technology transfer activities is also low. The total licensing income received by universities has been growing in recent years, but even today only amounts to about 4% of their total research and development volume (\$1.3 billion in FY 2003⁷, compared with total research revenues of about \$32 billion in 2002 – the most recent year for which data are

⁵ Reliable data on university-related new business starts is hard to come by. The Association of University Technology Managers (AUTM) keeps track of U.S. startups that have directly licensed intellectual property from universities. In FY 2003 the number of such startups was 374, down from a peak of 424 two years earlier (AUTM Licensing Survey, reported in Aaron Bouchie, “Survey reveals U.S. university licensing up, startup formation down”, news@nature.com, published online, 13 January 2005.) The *total* number of companies started by university faculty, staff, students, and alumna/e is certainly much larger, but comprehensive statistics for this are not available. A study conducted in the mid-1990s found that MIT faculty and graduates had founded about 4000 companies. At that time, MIT had only licensed intellectual property to about 200 startups. If we assume that the same 20:1 ratio applies today for the entire population of U.S. universities, the total rate of university-related business starts should be roughly 8,000 per year. By comparison, the rate of new business formation of all kinds exceeds 550,000 firms per year. (See U.S. Small Business Administration website, <http://www.sba.gov/advo/research/>.) Of course, this simple numerical comparison does not reflect what is likely to be the considerably higher probability that university startups take up new technology than the average new business. Nor does it account for the possibility that university-linked startups may have a higher rate of survival than average. Even so, it is important to keep in perspective the contribution of university-related startup activity to the overall economic and employment growth effect of new business formation.

⁶ For example, the ten leading corporate patenters in the U.S. in 2004 each received more than 1300 patents in that year, compared with 135 and 132 for, respectively, Caltech and MIT, the two most prolific university campuses.

⁷ See Bouchie, *op.cit.*

available.⁸⁾ Moreover, most of the royalty income is generated by a handful of highly remunerative licenses. The vast majority of university patents yield no royalty income at all. The distribution of income is thus highly skewed, and, although most technology licensing offices do not report their net financial performance, it is probable that many of them do not break even.⁹ Technology licensing officers at some leading U.S. universities often say that university technology transfer should be seen more as a public service than as a mechanism for income maximization, and the numbers bear them out. But that view is not universally shared by university administrators.

Finally, patenting and licensing is only one of a number of pathways for the transfer of knowledge from universities to industry. Firms may alternatively exploit recent university research results published in the open literature; or they may use university scientists as consultants to apply well-established engineering or scientific knowledge to the development of a particular product; or they may collaborate with university scientists and engineers to apply new scientific knowledge developed by researchers at other universities; or they may recruit the students of the leading university researcher in the field.¹⁰ Several recent studies have suggested that patenting and licensing is not the most important of the available pathways.¹¹ This is also the view of academic researchers themselves. According to a recent survey of nearly 70 faculty members in the MIT Departments of Mechanical Engineering and Electrical Engineering and Computer Science, all of them patent holders and thus presumably having an above-average inclination to use this channel, patenting and licensing

⁸ National Science Board, *Science and Engineering Indicators – 2004*, Appendix Table 4-4. Since several years typically pass between research activity and the resulting flow of product royalties, a more appropriate ratio might be between current royalty income and total R&D expenditures of, say, a decade earlier. That ratio is somewhat greater – 6% – but the basic conclusion, that royalty payments in the aggregate will never be more than a small fraction of research revenues, is unchanged.

⁹ According to the Association of University Technology Managers, 21,000 active technology licenses were held by U.S. universities in 2001, generating about \$1.2 billion in gross revenues in that year. Of these, only 125, or 0.6%, yielded \$1 million or more (AUTM, 2002). An unpublished study by Ashley Stevens of Boston University's technology transfer office estimated that about half of the TLOs in his national sample made a net positive financial contribution to their institution after accounting for operating expenses. (See Ashley J. Stephens, "Do Most Academic Institutions Lose Money on Technology Transfer?", presented at the 2005 Annual Meeting of the Technology Transfer Society, Kansas City, MO (available at http://www.kauffman.org/pdf/tt/Stevens_Ashley.pdf).

¹⁰ For a useful discussion of these possibilities, see Lee Branstetter and Kwon Hyeog Ug, "The Restructuring of Japanese Research and Development: The Increasing Impact of Science on Japanese R&D", RIETI Discussion Paper, 04-E-021, April 30, 2004.

¹¹ See, for example, Wesley Cohen, Richard Nelson, and John Walsh, "Links and impacts: The influence of public research on industrial R&D", *Management Science*, vol. 48, no. 1, January 2002, p. 1.

activity was perceived to be responsible for less than 7% of the knowledge transferred out of the university. Faculty consulting, publication, and the recruiting of students were all ranked significantly higher (see Figure 1).¹² It is often said that the best form of technology transfer is the moving van that transports the PhD from his or her university laboratory to a new job in industry.

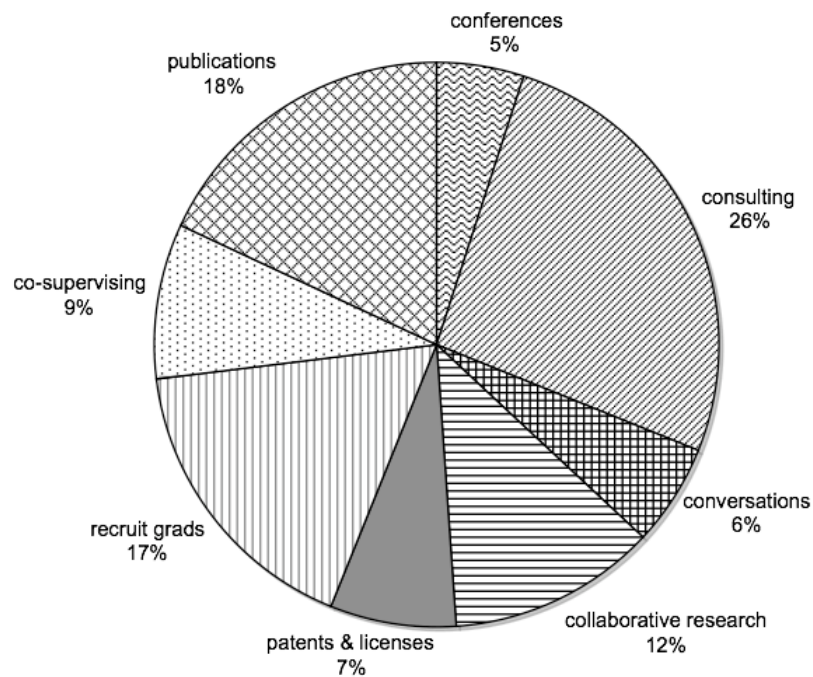


Figure 1: Perceptions by MIT faculty patentholders of relative importance of alternative channels of knowledge transfer from university to industry

Source: A. Agarwal and R. Henderson, “Putting patents in context: Exploring knowledge transfer from MIT”, *Management Science*, vol. 48, no. 1., January 2002, p. 44.

Of course, these comparisons do not capture all of the benefits of university patenting and licensing – for example, the stimulus to entrepreneurial thinking among faculty and students that these activities often provide. But this only underscores the need for a broader view of the university’s role in local economies – as creators, receptors, and interpreters of innovation and ideas; as sources of human capital; and as key components of social infrastructure and social capital.

¹²A. Agarwal and R. Henderson, “Putting patents in context: Exploring knowledge transfer from MIT”, *Management Science*, vol. 48, no. 1., January 2002, p. 44.

The Local Innovation Systems Project

In 2002, in an effort to develop this broader perspective, an international team of researchers based at the MIT Industrial Performance Center began studying specific cases of industrial transformation in different locations. The overall goal of the Local Innovation Systems Project is to examine the role of innovation in the emergence and transformation of local industries. In the first phase of research, we have focused on the contribution of universities to local industrial development through their participation in local innovation processes.

We adopted an ‘outside-in’ perspective on the university role. Our starting point was that the local economy in which a university is situated can be described as a set of industries, each of which produces a mix of products and/or services that changes over time. The economic health of the economy depends ultimately on the outcome of these evolutions. A successful local economy is one in which significant numbers of local firms adapt to new market and technological opportunities by introducing commercially successful new products or production processes repeatedly over time. Not all local economies adapt with equal success, and within the same locale different industries perform differently. The outcome depends at least partly on the abilities of local firms to *take up* new technologies, and new knowledge more generally, and to *apply* this knowledge productively. Our focus is on the contributions made by local universities to those capabilities.

This perspective differs from the conventional view of the university’s role in its local economy in a number of ways:

- By focusing on the capacity of local firms to take up and apply new knowledge, we allow for the possibility that universities, in addition to serving as sources of such knowledge, may contribute in other ways too.
- By describing the local economy in terms of an existing set of industries, we allow for the possibility that university contributions may not be limited to the formation of new firms or the creation of new industries.

- By taking as our initial unit of observation the local industrial economy, rather than the university itself or the flows of people, technology, and ideas that emerge from it, we can deal more straightforwardly with situations in which the university is only a minor supporting player in a larger industrial development process.
- By defining economic success in terms of the ability to adapt to new market and technological opportunities – many of which originate elsewhere – we acknowledge the importance of external influences on local industries, rather than treating them as a more or less self-contained clusters and focusing exclusively on their internal structure and processes.
- By focusing on the process of industrial transformation, and specifically the change in the mix of products and services produced by an industry over time, our perspective is dynamic rather than static, and extends over periods of years or even decades, rather than focusing on immediate outcomes.

We conducted our research in 22 locations. In each case we focused on a particular industry or line of business (in one location we studied two industries.) The portfolio of case studies is listed in Table 1. Industrial transformation is not a one-time event but rather a continuing process. In each case we selected a time period for study which generally ranged between two and three decades. We traced the development of the industry over this period, focusing on the contribution of local innovation processes to the evolution of products, services, and production processes.

Table 1: The Local Innovation System Project Case Study Portfolio

Country	Location	Industry/technology
USA	Rochester, NY	Opto-electronics
USA	Akron, OH ,	Advanced polymers
USA	Allentown, PA	Opto-electronics/steel
USA	Boston, MA	Bioinformatics
USA	New Haven, CT	Biotechnology
USA	Charlotte, NC	Motor sports (NASCAR)
USA	Greenville-Spartanburg, SC	Autos
USA	Alfred-Corning, NY	Ceramics
USA	Youngstown, OH	Steel/autos
Finland	Tampere	Industrial machinery
Finland	Turku	Biotechnology
Finland	Seinajoki	Industrial automation
Finland	Pori	Industrial automation
Finland	Helsinki	Wireless
Finland	Oulu	Medical Instruments
UK	Central Scotland	Opto-electronics
UK	Aberdeen	Oil and gas
UK	Cambridge	Bioinformatics
Taiwan	Taipei-Hsinchu	Electronics
Taiwan	Taipei-Hsinchu	Software
Japan	Hamamatsu	Opto-electronics
Japan	Kyoto	Electronics
Norway	Stavanger	Oil and gas

The industries in our sample include both mature sectors (industrial machinery, automobile manufacturing) and new fields (bioinformatics, opto-electronics.) The locations include relatively prosperous, ‘high-tech’ regions (Boston, MA, Cambridge in the UK) as well as economically less-favored regions (Youngstown, OH, Allentown, PA). About half of the locations are outside the United States. Some of the locations are home to first-tier research universities, others to universities that are not in the front rank, and still others have no

universities at all. Thus, though constructed opportunistically rather than scientifically, our case portfolio incorporates a broad range of technological, industrial, and institutional environments.

We used a comparative and primarily historical and qualitative approach to the research. Where possible, we selected at least two locations that were matched in the sense that each was home to the same industry. In principle the use of rigorously matched pairs should make it possible to move from single idiosyncratic and isolated cases to a more generalizable causal model. In practice even the matched cases have many dimensions of difference which cannot be controlled. As such, the main benefit of comparison is not so much to enhance the generalizability of findings as to inject greater rigor into the qualitative understanding of the cases, particularly by drawing contrasts between them.

The principal mode of data collection in each location was to carry out in-depth interviews with business practitioners, university researchers and administrators, and national and local economic development officials and policymakers, using semi-structured questionnaires. We augmented these interviews by using local and regional business and economic databases, as well as patent and publication data as appropriate, reports, archival materials, and published sources concerning the local economy, local universities, and other local institutions.

Between 2002 and 2005 we conducted 714 interviews in the U.S., U.K., Norway, Finland, and Japan.¹³ 50% of these interviews were carried out at firms, and another 30% at universities. The breakdown by country is shown in Table 2. Additional breakdowns are included in the Appendix.

¹³ An additional 117 interviews were conducted between 1999 and 2003 on the electronics and software industries in the Taipei-Hsinchu corridor in Taiwan. These interviews were carried out as part of a separate project at the Industrial Performance Center, the IPC Globalization Study (see Suzanne Berger and Richard K. Lester, *Global Taiwan*, M.E. Sharpe, 2005, and Suzanne Berger, *How We Compete*, Doubleday, 2006 (forthcoming)). We drew on this research for the LIS Project, but have not included it in the LIS interview statistics.

Table 2: LIS Project Interviews, By Country (2002 –2005)*

	Number of interviews
United States	258
Finland	238
United Kingdom	103
Japan	84
Norway	31
TOTAL	714

*A further 117 interviews were carried out in Taiwan under the auspices of a separate IPC research project.

General Findings

Each of the cases is unique. The wide variety of industrial transformations occurring in the different regions as well the varied roles played by local universities in these events is suggested by the four case summaries presented in the accompanying boxes. To bring some order to the mass of evidence we accumulated in our research, we found it useful to introduce a simple typology of industrial transformation processes.

- I. Indigenous creation:** The first type of process is the emergence of an industry that has no technological antecedent in the regional economy – that is, it entails the local creation of an entirely new industry. This, of course, is the kind of process that tends to be associated with universities. A well-known example is the development of the personal computer industry in Silicon Valley, although it is not a perfect example since the PC industry had clear industrial antecedents in the region including the semiconductor sector.¹⁴ Examples from our cases are the development of the biotechnology sector in the region around New Haven, CT, and the development of the wireless industry in the Helsinki region. Here too it is possible to identify industrial precursors, and the examples make the point that the

¹⁴ For an account of the development of Silicon Valley dating back to the early years of the last century, see Timothy J. Sturgeon, “How Silicon Valley Came to Be”, in Martin Kenney (ed), *Understanding Silicon Valley, Understanding an Entrepreneurial Region*, Stanford University Press, 2000.

emergence of an industry that is entirely without antecedent in the region is actually a very rare event.

II. Transplantation from elsewhere:

This type of process also entails the development of an industry that is new to the region. But in this case the primary mechanism is the importation of the industry from elsewhere.

Examples from our cases include the establishment of a major automotive industry cluster along the I-85 corridor in Upstate South Carolina after a major BMW manufacturing facility was brought to the region. Another example is the arrival of major oil exploration, production, and service companies in Stavanger, Norway and Aberdeen, Scotland following the initial discoveries of oil resources in the North Sea, which in turn provided the basis for the development of significant oil and gas industry agglomerations in the two locations.

III. Diversification into technologically-related industries:

This category refers to transitions in which an existing industry in a region goes into decline, but its core technologies are redeployed and

Stavanger and Aberdeen – Oil and Gas From Black Gold to Human Gold

Stavanger, the largest municipality in Rogaland County on the southwest coast of Norway, and Aberdeen, in northeast Scotland, have been at the center of offshore oil and gas industry development in the North Sea for nearly 40 years, since the initial discoveries of North Sea oil were made in the 1960s. The two regions developed over the same period, working with the same group of global oil industry companies, and facing similar market conditions and geological and technological challenges. But the development of local technological and industrial capabilities followed very different paths. In Norway, the national, regional and local authorities made concerted efforts to develop local capabilities in the oil and gas industry, and to concentrate industry-related institutions in Stavanger. The strategies included the creation of a national oil company, specific licensing conditions to require foreign companies to assist in technology transfer to local industry, and the development of higher education and research capacities in key related fields, including the creation of a new technical college (later a university) and a new public research institute in Stavanger. These strategies helped existing local industries such as shipbuilding and construction to enter the oil and gas industry, and also helped emerging local companies to grow and become competitive internationally. In contrast, the industry in Aberdeen grew despite the lack of consistent support from the national and local authorities. British localization policies were less focused on agglomerating industry-related capabilities in a single place. Technology policies for the industry were also less focused in the UK, and tended to change over time. And there was no systematic effort to develop education or research capabilities at local universities. The two universities in Aberdeen have played much less visible roles over the years than their counterparts in Stavanger, and have far fewer contacts with the local industry today.

These differences in the institutional and policy environment in Stavanger and Aberdeen, though considerable, do not appear to have led to significant differences in the international competitiveness of the two local industries, at least so far. Stavanger and Aberdeen are characterized by very different local innovation systems, but both appear to have enjoyed similar successes in the race to internationalize and export their expertise to other oil provinces. The oil fields in the North Sea province are now maturing, production costs are rising, and the attention of the international oil industry is beginning to shift elsewhere as economically attractive new oil-producing regions open up around the world. Although the oil and gas industry will remain vital to the economies of Aberdeen and Stavanger for many years to come, both regions now confront the challenge of maintaining their prosperity and growth once North Sea production begins to decline. Will these regions be able to sustain an industrial base that is less dependent on their natural resources? Will they be equally successful in making the transition from a resource-based to a knowledge economy?

Researchers: Sachi Hatakenaka, Petter Westnes, Martin Gjelsvik, Richard Lester, and Wei Gao

provide the basis for the emergence of a related new industry. Examples from our cases include the development of a polymer engineering and manufacturing industry in Akron, Ohio on the heels of the tire industry's disappearance from that city, once known as the tire capital of the world.

IV. Upgrading of existing industries:

This type of transition entails the upgrading of an industry in a region through the infusion of new production technologies or the introduction of product or service enhancements. Examples from our cases include the revitalization of the industrial machinery sector in Tampere, Finland, where the integration of electronics, control, and communication technologies into traditional mechanical engineering product systems helped a group of local manufacturers achieve global competitiveness in the highly specialized industrial machinery markets serving the forestry, paper, and transportation industries. In another Finnish example, biotechnology played a role in upgrading the traditional pharmaceutical and food industries in Turku, in southwestern Finland.

Akron – Advanced Polymers Out of the Ashes

Until the 1980s Akron, a medium-sized industrial city in northeast Ohio, was the 'tire capital of the world'. Today not a single tire is produced there. Yet many of the original companies – or at least parts of them – remain located there and have shifted their emphasis to polymer production. The tire companies initially responded to the loss of their competitive position by moving production out of Akron to lower cost environments, as well as through a program of diversification, acquiring unrelated companies in faster growing industries, usually also located elsewhere. They also began to invest more heavily in developing new, faster-growing applications of their core technology, polymer chemistry and engineering. They focused on markets for commodity polymers in industries such as aerospace, building materials, and automobile manufacturing. Later they sought to develop capabilities for the production of customized polymer products. Local civic and business leaders saw the local capabilities in polymer engineering as a foundation of the city's economic future, and, fearful that their city would follow the 'hollowing out' path that many of their rust-belt neighbors had experienced, called on local universities to take a more active role in supporting companies' innovation efforts in this field. These efforts were not entirely successful. The University of Akron initially focused on technology transfer to the large industrial polymer producers, and sought to provide a window on its technology for these firms. But the firms didn't see much of value emerging from the university's laboratories, and some had already developed sophisticated strategies for interacting with universities nationally. Later the university put greater emphasis on entrepreneurship, and on building technical connections among local firms – small, medium and large – that had previously been disconnected from each other.

Researcher: Sean Safford

These four types of transformation are idealized. In practice the distinctions between them are not always clear. For example, when the firms in a local industry move along the value chain from components to systems (the Kyoto electronics manufacturers) or from systems to associated services (the Tampere machinery producers), do these represent cases of

upgrading (Type IV) or diversification (Type III)? Furthermore, the development of an industry in a particular location may involve more than one kind of transition at the same time. For example, the initial development of the oil and gas industry in Stavanger was made possible by the decisions of multinational oil firms to locate there, but local engineering, construction, and shipbuilding firms diversified into the new industry and later achieved international successes in this field. (In Aberdeen only one local firm, a fishing and ship repairing concern, made that transition.)

Despite these complications the taxonomy is useful. For most of the cases, one type of transition clearly dominated (see Table 3). And taken together, the cases strongly suggest that the skills, resources and institutional capabilities associated with each type of transition are different, and that each is associated with a distinct pattern of technology take-up and application. The roles of local universities also appeared to vary considerably depending on which kind of transition was occurring.¹⁵

**Tampere – Industrial Machinery
From Old-Tech to High-Tech**

Tampere, in south-central Finland, is home to a cluster of industrial machinery firms whose roots in the region date back more than half a century. Like similar clusters in Europe and the U.S., the machinery industry in Tampere underwent a long period of decline beginning in the 1970s, aggravated in this case by the disintegration of the Soviet economy which until 1989 had been the main export market for Tampere's machinery firms. But the Tampere industry today includes several world market leaders in specialized niches in mobile heavy machinery, large-scale process machinery, and automation systems. These firms are supported by a concentration of sub-contractors and parts providers. Strong areas of regional expertise include machine automation, mobile hydraulics, dynamic system control, and process control and automation. An important contributor to the Tampere industry's resilience has been the successful infusion of new technologies into traditional machine-building, including electronics, control, information, and wireless communications technologies. A key trend has been the progressive addition of 'intelligence' to production, process, and mobile machinery by embedding electronic modules and associated software capable of controlling the electrical and mechanical functions of the machines in their complex environments. This synthesis of the traditional with the new was helped by the presence in the region of a sizeable group of information and communications technology firms, anchored by a Nokia research center. National research and development organizations like the Technical Research Center of Finland (VTT) were influential in generating new knowledge and transferring knowledge and technology across technologies and disciplines. Tampere University of Technology (TUT) also played an important role as a provider of skilled labor, technical know-how and problem-solving abilities relevant to local firms. TUT's role, and regional technical cooperation more generally, was facilitated by the structure of Tampere's machinery industries, in which the leading firms depend on the same set of core technologies (hydraulics, control, automation, etc.) but compete globally in distinct markets.

Researchers: Carlos Martinez-Vela and Kimmo Viljaama

¹⁵ In addition to the taxonomy described here, we considered other typologies of industry clusters, industrial districts, and regional economies discussed in the literature. We discarded most of them because they are static, whereas our focus on innovation processes brings economic transitions to the fore and calls for a dynamic scheme. Markusen has identified several types of industrial districts: Marshallian, hub and spoke, satellite, and state centered (see Ann Markusen, "Sticky Places in Slippery Space", *Economic Geography* 72(3): 293-313 (1996)). Although this too is a static typology, we experimented with it in order to generate dynamic categories. This is a promising approach that deserves further work.

Charlotte – NASCAR
Unplanned Combustion

Charlotte, the largest metropolitan area in North Carolina, is well known as the second largest financial center in the United States. The Charlotte region is also the base of operations of the second most popular and fastest growing spectator sport in the United States, NASCAR motor racing. It is home to the vast majority of the teams competing in the weekly NASCAR (National Association of Stock Car Auto Racing) races. The race teams are the anchor of a diversified industrial agglomeration that also includes speedways, parts manufacturers and suppliers, and specialized technical and service providers ranging from engine manufacturing and aerodynamic modeling and testing to marketing and media. The industry today provides thousands of jobs in the region and is a magnet for people who want to get involved in motor racing. This development has occurred without significant support or planning by regional, state, or local authorities.

During the last 15 years NASCAR has been transformed by technology and engineering. From its origins fifty years ago in the backyards and garages of local hobbyists, Charlotte's 'NASCAR Valley' has grown into a multi-billion dollar industry rich in engineering science and technology with links to knowledge and industrial communities around the United States and overseas. The race teams employ a highly skilled workforce engaged in R&D, engineering, marketing and other specialized activities. The major teams have relationships with suppliers and testing facilities throughout the United States and sometimes Europe. They rely on a specialized network of parts and service suppliers, all of which are present in the Charlotte region. Some of the suppliers have diversified and now sell into the high-performance parts aftermarkets for autos, motorcycles, and boats, as well as other forms of auto racing. The race cars themselves are strictly regulated by NASCAR. The basic engine and vehicle architectures have been frozen for more than forty years, and allowed changes in design are closely controlled. But performance enhancements are made from week to week, and technologies such as modeling and simulation, rapid prototyping and machining, and sophisticated instrumentation and data acquisition systems help the teams to continually test and modify the cars within the very tight time constraints imposed by the weekly race schedules.

Local colleges and universities are now seeking to increase their involvement. Several have launched motor sports education and research programs, and the University of North Carolina at Charlotte is home to one of the leading motor sports education programs in the nation. But interactions between the NASCAR industry and local universities have been very limited so far. The race teams are typically unwilling to divulge their secrets, especially to local universities which are in no position to prevent the diffusion of information to rival teams. And the teams' need to find fixes for technical problems within a matter of days is usually incommensurate with universities' more leisurely approach to problem-solving. The major contribution of local universities and colleges has been in the education and training of specialized personnel. But on-the-job training is mandatory in the industry and even here there are limits to what the colleges and universities can do.

Researchers: Carlos Martinez-Vela and Kimmo Viljaama

Table 3: The Case Studies, By Dominant Transition Pathway

Country	Location	Industry/technology	Dominant transition pathway*
USA	Rochester, NY	Opto-electronics	III
USA	Akron, OH ,	Advanced polymers	III
USA	Allentown, PA	Opto-electronics/steel	II
USA	Boston, MA	Bioinformatics	I
USA	New Haven, CT	Biotechnology	I
USA	Charlotte, NC	Motor sports (NASCAR)	I/IV
USA	Greenville-Spartanburg, SC	Autos	II
USA	Alfred-Corning, NY	Ceramics	IV
USA	Youngstown, OH	Steel/autos	
Finland	Tampere	Industrial machinery	IV
Finland	Turku	Biotechnology	IV
Finland	Seinajoki	Industrial automation	IV
Finland	Pori	Industrial automation	IV
Finland	Helsinki	Wireless	I
Finland	Oulu	Medical Instruments	I
UK	Central Scotland	Opto-electronics	I
UK	Aberdeen	Oil and gas	II
UK	Cambridge	Bioinformatics	I
Taiwan	Taipei-Hsinchu	Electronics	II
Taiwan	Taipei-Hsinchu	Software	I
Japan	Hamamatsu	Opto-electronics	I
Japan	Kyoto	Electronics	III/IV
Norway	Stavanger	Oil and gas	II

* I = indigenous creation; II = transplantation; III = diversification; IV =upgrading

In every case, the outcome of the transition hinged on the ability of the firms in the region to identify new technological and market opportunities, and to develop or absorb and then apply new technological and market knowledge. In every case it was the actions of

individual firms, motivated by profit, responding to market signals, and applying their knowledge of the marketplace that ultimately determined the outcome. But in every case, too, the innovation performance of these firms depended on more than their own internal capabilities and strategies. It was also affected by the behavior and performance of local supplier and customer firms, producers of complementary goods and services, and financial intermediaries, as well as local and regional education and training institutions, universities, other public research institutes and foundations, and government agencies and programs concerned with innovation, both promotional and regulatory. Less tangible attributes of the locale were often also important, such as attitudes towards innovation and entrepreneurship, and the quality of local leadership. All these elements comprise the local innovation system, and our cases make clear that the demands placed on such systems – and thus their required attributes – vary depending on what kind of transition is involved.

A comparison of the indigenous creation (Type I) and upgrading (Type IV) pathways helps to make the point. Consider financing, for example. In cases of new industry formation, at least for the science-based industries we studied in this project, financing originated mainly from some combination of the founders themselves, their friends and family members, angel investors, and professional venture capital firms. In contrast, for the upgrading of existing industries, new product or process development was financed mainly with internal company funds, or in some cases by customers or suppliers. Government-funded demonstration projects also played a role in some cases. In cases of new industry formation the dominant innovation culture was science-driven and entrepreneurial, whereas in cases of upgrading the innovation processes were more likely to be customer driven and influenced by total quality principles and practices. In cases of new industry creation a local university or public research laboratory typically played the role of anchor institution, whereas in the case of industry upgrading the anchor institution was more likely to be a lead firm or a lead customer. In science-based industry formation the highest-impact educational outputs of local universities were Ph.D.-level scientists and engineers with an interest in entrepreneurial careers and some exposure to entrepreneurial business practices. For cases of upgrading, bachelors and masters-level engineering graduates equipped with knowledge of the industry's practices and problems obtained from classes, practical theses, and internships were of greatest value. For science-based industry creation, university technology transfer was pro-

active and oriented towards start-ups and small firms. For industry upgrading these arrangements were more likely to center on long-term relationships between the university and established firms. In some of the cases of new industry creation (though not all) a local university played a leading role. But none of the upgrading processes were university-led, although in some cases local universities played important supporting roles.

In the next section the university contribution to these transition processes is described in more detail.

University Participation in Local Industrial Transformations

Our cases make clear that universities engage with their local communities in many different ways. We focused in these cases on the university role in local innovation processes, but there are many other dimensions of engagement that we did not consider. Universities may provide important cultural, intellectual, architectural, aesthetic, artistic, athletic, recreational and medical resources to their communities. University students and staff may participate in important local social projects. University graduates, if they remain in the area, will contribute to the lives of their communities in countless ways. It might even be argued that universities contribute to family cohesion; without a good local university, young people will be forced to leave to pursue their studies, and are less likely to return afterward.

Even within the purely economic domain there are important aspects of the university role that we did not consider. In many communities the university is one of the largest employers, and it is often a major consumer of products and services produced by the local economy. Universities may also be important owners of local real estate. A university's contribution to local innovation processes is thus only part – often just a small part – of its local presence. But even within this relatively narrow frame our cases revealed multiple channels of engagement, which can be grouped into four broad categories:

- **Education and training.** Universities make important contributions to local human capital development at the undergraduate, masters, doctoral, mid-career, and executive education levels.
- **Adding to the stock of codified knowledge.** This includes publications in the technical literature, patents, and software and hardware prototypes.
- **Increasing the local capacity for scientific and technological problem-solving.** This includes various forms of support for the creation and development of new technology-based enterprises, such as venture mentoring programs, start-up clinics, and incubators. It also includes contract research carried out by university researchers for industry, cooperative research projects carried out jointly by university and industry researchers, faculty consulting, and technology licensing. Universities may also contribute by giving local firms access to specialized instrumentation and equipment.
- **Providing space for open-ended conversations about industry development pathways and new technological and market opportunities.** These ‘public spaces’ – some of them focused on particular industries, others not – include university-hosted meetings and conferences, standard-setting forums, forums for potential investors (pre-seed, seed, angel, and venture capital investors), business plan contests, industrial liaison programs, alumni networking activities, and visiting committees and curriculum development committees involving local industry practitioners.

The impacts of these activities may extend far beyond the university’s own neighborhood. This is most obviously true of the great research universities. These are genuinely international institutions, educating students from around the world, contributing to the international research literature, interacting with firms and governments from many countries, and employing on their faculties internationally recognized intellectual leaders from around the world. But even for these ‘global’ universities, the economic impact of

their activities is skewed towards their local communities. For other universities the economic impacts are even more heavily skewed to the local.¹⁶

The distinction between the problem-solving and public space roles of universities has been discussed previously,¹⁷ and appears to be well recognized by many firms. A related study, which sought to determine what firms look for in their university relationships, examined twenty-one university research centers and nearly two hundred collaborating firms. It found that for some firms the main goal was to enlist university researchers in problem-solving activities directly related to their primary business. In these interactions the impact on the company's bottom line was the dominant measure of performance. But for other firms the most important goals of their interactions with the university were to participate in activities and exchanges that would enable them to become privy to the latest thinking in fields relevant to their business, and to have an influence on the future direction of related curricula at the university.¹⁸ Firms in the second category tended to be larger, and the universities with whom they collaborated tended to be those in the elite group. The more problem-solving-oriented collaborations were more likely to involve small and medium-sized firms and lower-ranked universities.

The most important finding from our cases is that the university role in local innovation processes depends on which industrial transition pathway is being followed. Although it is common to find many if not most of the activities listed above at any given university, we observed a tendency for certain activities to be most closely associated with particular development pathways.

For Type I transitions involving the creation of a new science-based industry, important activities include providing various kinds of support for new business formation, pro-active

¹⁶ The Association of University Technology Managers reported that 84% of the nearly 500 companies formed in 2001 based on university technology were located within the same state as the university source. See also James D. Abrams, "Comparative localization of academic and industrial spillovers", NBER Working Paper 8292, National Bureau of Economic Research, Cambridge, MA, May 2001, and A. B. Jaffe, M. Trajtenberg, and R. Henderson, "Patent Citations." *The Quarterly Journal of Economics*. Volume CVIII.3:577-598 (1993).

¹⁷ See Richard K. Lester and Michael J. Piore, *Innovation – The Missing Dimension*, Harvard University Press, Cambridge, MA, 2004.

¹⁸ Michael Santoro and Alok Chakrabarti, "Corporate strategic objectives for establishing relationships with university research centers," *IEEE Transactions on Engineering Management*, 48, no. 2., May 2001.

technology licensing programs and policies, and efforts to broker ties between academic researchers and local entrepreneurs. Key individuals at the university may also play important roles in establishing an identity for the new industry, convening conferences and workshops, initiating standard-setting activities, and generally acting as industry ‘evangelists’ by drawing attention to the existence of local concentrations of related activities and by painting a picture of future impact and growth potential.

For Type II transitions involving the relocation of industries into the region, important university activities include responding to the local manpower needs of the relocating firms, especially by developing new, customized curricula and continuing education programs. Another important role is to provide technical assistance to local suppliers and sub-contractors.

For Type III transitions involving diversification out of existing local industries into technologically related new ones, a key role for the university is to cultivate technological links between disconnected actors, for example by establishing on-campus forums for discussion of new applications of local industrial technologies. Another important role is to help build the identity of the new industry locally.

Finally, for Type IV transitions involving the upgrading of the technological base of existing industries, local universities contribute to technical problem-solving through contract research and faculty consulting, develop industry-relevant degree and continuing education programs, create student internship and faculty leave opportunities in the local industry, convene foresight exercises and user-supplier forums on campus to discuss the future development of the industry, and participate in global best-practice scanning activities with local industrial practitioners.

The patterns of university activity associated with each type of industrial transformation process are summarized in Figure 2.

University roles in alternative regional innovation-led growth pathways

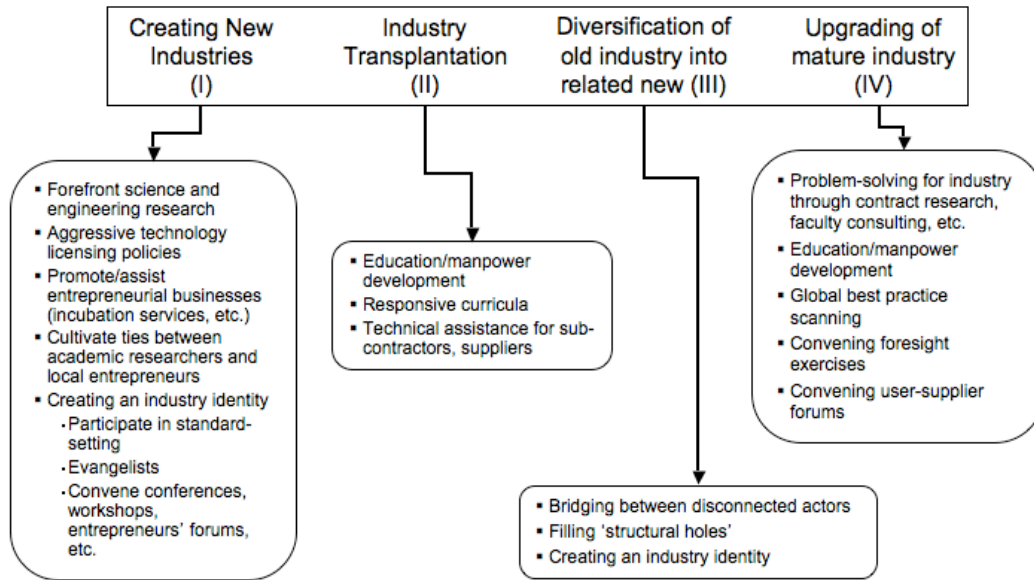


Figure 2: University roles in alternative innovation-led local/regional growth pathways

These findings cast further doubt on the utility of a one-size-fits-all approach to economic development that so many universities have been pursuing, with its focus on patenting, licensing, and startups. They instead suggest the need for a broader, more differentiated view of the university role. Not all local economies are like Silicon Valley; not all industries are like biotechnology or software; and not all universities are like Stanford. University leaders responsible for the economic development mission need to understand the particular circumstances and needs of local industries, as well as the strengths and weaknesses of their own institutions. These leaders need to understand the pathways along which local industries are developing and the innovation processes that are associated with those pathways. And they should seek to align the university's contributions to local economic development with what is actually happening in the local economy. The outcome will not be the same for every university. Indeed, it will likely be different in different parts of the same university to the degree that different industries are present in the region.

This discussion points to the need for a strategic awareness of local industrial developments going well beyond the norm even at universities with a strong tradition of working with

industry. It further suggests the need for a strategic approach to the economic development role within the university itself. But how realistic is this idea of strategy for universities – notoriously fragmented and fractious organizations, whose famous portrayal decades ago by University of Chicago President Robert Hutchins as a collection of separate departments held together by a heating system seems equally apt today? A university, with its decentralized management structure and its multiple stakeholders, each with different and often conflicting goals, lacks the organizational coherence of a business enterprise. Precisely because of this, however, it is important for university administrators to be clear about the goals they are seeking in the economic domain and how they intend to achieve them. It is equally important for these administrators to be clear about what they do not seek to achieve. In this domain, as in others, universities cannot be all things to all people, and a failure to formulate and clearly articulate an institutional strategy for economic development risks underperformance in this domain, interference with other institutional goals, increased conflict within the university, and disappointed external constituencies. Finally, an economic development strategy is important because – at least within the decentralized, competitive American higher education system – universities compete with each other for faculty, students, and research funds. Competing successfully depends partly on being able to do the same thing that rivals do only better, and partly on being able to differentiate oneself from one’s rivals. A well-designed, effectively implemented strategy for engaging with the local economy can contribute to both goals.

Conclusions

Local economies thrive to the degree that local firms succeed in adapting to new market and technological opportunities through innovation in products, services, and production processes. This innovation performance hinges in turn on the ability of local firms either to develop new technological and market knowledge themselves or to acquire it from elsewhere and then apply it productively. Our study has shed light on how universities can strengthen these local innovative capabilities:

- 1. Universities have multiple ways to contribute to local innovation processes directly.** The possibilities are not limited to patenting and licensing discoveries made in university laboratories. In addition to their own discoveries, universities can help to attract new knowledge resources from elsewhere. They can help to adapt knowledge originating elsewhere to local conditions. They can help to integrate previously separate areas of technological activity in the region. They can help to unlock and redirect knowledge that is already present in the region but not being put to productive use. Most of these university contributions presuppose the presence of local industry.
- 2. In most cases, the indirect support provided by universities for local innovation processes is likely to be more important than their direct contributions to local industry problem solving.** The most important of these indirect contributions is education. But a university can also play an important role as a public space for ongoing conversations, involving local industry practitioners, about the future direction of technologies, markets and local industrial development. This public space can take many forms, including meetings, conferences, industrial liaison programs, standards forums, entrepreneur/investor forums, visiting committee discussions of departmental curricula, and so on. The conversations between university and industry people that occur in these spaces are rarely about solving specific technical or commercial problems. But they often generate ideas that later become the focus of problem-solving both in industry and in universities. The importance of the public space role of the university and its contribution to local innovation performance is frequently underestimated.
- 3. The conditions, practices, and attitudes that lead to successful technology take-up and application in local industries depend on the specific characteristics of the industry and its development pathway.** Our studies make clear that industry upgrading, industry diversification, industry importation, and industry creation are each associated with different local patterns of technology take-up and application. More specifically, for each type of

transition we observed a distinct pattern of university participation in the local innovation system.

- 4. Universities should approach their role in local innovation processes strategically.** This means developing an understanding of the particular circumstances and needs of local industries and the strengths and weaknesses of their own institutions, and it means seeking a fit between local industry needs and internal university capabilities. Universities should discard the one-size-fits-all approach to technology transfer in favor of a more comprehensive, more differentiated view of the university's role in local economic development.

- 5. A strategic approach to the local economic development role is compatible with the pursuit of excellence in the university's traditional primary missions in education and research.** Indeed, success in these primary missions is a necessary condition for contributing effectively to innovation and growth in the local economy. The fear that these missions will somehow be harmed is not a good reason for universities not to embrace their role in local innovation processes.

APPENDIX

Local Innovation System Project Interview Data

Table A-1: LIS Project Interviews, By Industry

	Number of interviews
Materials (steel, synthetic rubber, polymers, ceramics)	75
Machinery/automation	98
Motorsports	57
Automotive	19
Biotech	66
Bioinformatics	32
Imaging/optoelectronics/electronics	183
Medical/wellness	40
Wireless	51
Oil and gas	71
Miscellaneous	22
TOTAL	714

Table A-2: LIS Project Interviews, By Location

	Number of interviews
Tampere, Finland	39
Seinajoki, Finland	33
Helsinki, Finland	61
Oulu, Finland	40
Pori, Finland	29
Turku, Finland	36
Youngstown, OH	24
Allentown, PA	21
Akron, OH	18
Rochester, NY	33
Alfred-Corning, NY	6
Boston, MA	33
New Haven, CT	30
Charlotte , NC	47
Greenville, SC	26
Aberdeen, Scotland	40
Cambridge, England	18
Central Scotland	45
Hamamatsu, Japan	40
Kyoto, Japan	44
Stavanger, Norway	31
Miscellaneous	20
TOTAL	714

Table A-3: LIS Project Interviews, By Type of Organization

	Number of interviews
Firms	355
Universities/public research institutions	211
Other (govt., finance, industry associations, etc.)	148
TOTAL	714

<http://web.mit.edu/lis/>

