Detecting university-industry synergies: A comparison of two approaches in applied cluster analysis

Edward Feser
Shannon Landwehr
University of Illinois at Urbana-Champaign

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Corresponding author: Edward Feser, Associate Professor, Department of Urban and Regional Planning, University of Illinois at Urbana-Champaign, 111 Temple Buell Hall, MC-619, Champaign, IL 61820 USA, feser@uiuc.edu

1 Introduction

As the practice of formulating regional development strategies around various concepts of industry clusters has grown, so has the variety of methodologies for detecting appropriate areas of policy intervention. A particular challenge for regions interested in facilitating the growth of technology-based industries and business start-ups is the conceptualization and measurement of the linkages between the regional science base, reflected most heavily in the region's universities but also in its non-academic research laboratories, and its industrial base (Paytas, Gradeck et al., 2004). According to most cluster theories, businesses are at the core of competitive clusters, with universities and other institutions forming a critical support infrastructure for continued industrial innovation and productivity growth. Following this view, many early applied regional cluster studies focused on detecting existing critical masses of businesses in related sectors, with the degree of "relatedness" varying from membership in the same industry (a crude sector-based approach), to membership in buyer-supplier chains, utilization of similar technologies, or linkages via formal or informal innovation flows (Cortright, 2006). The implication in such studies is that strategies should aim to further strengthen large concentrations of related industries—effectively the region's industrial specializations—since, by virtue of their large absolute and relative size, they represent clear regional competitive advantages.

Some of the problems with this perspective are immediately apparent in smaller regions, regions with a preponderance of large declining industries, and regions particularly interested in fostering innovation-oriented economic development. Small regions may have few or any groups of related sectors that have achieved a meaningful degree of critical mass (a "no clusters" problem).

Some regions' existing clusters may be in decline or growing slowly if at all (a "wrong clusters" problem). Well-known examples in the U.S. are Detroit (in vehicle manufacturing) and the Carolinas (in textiles and apparel). Other regions may see the goal of economic development policy as not to further strengthen already large regional sectors, but to encourage the growth of new technology-based industries that can represent the next economic base as larger industries inevitably decline (a "new clusters" problem). Interestingly, few contributors to the literature conclude that cluster notions are uninformative for development planning purposes in such circumstances. Rather, the thrust in the both academic and applied literatures increasingly is that clusters follow life cycles, just as sectors do, and that studies should distinguish between *existing* (declining or regenerating) clusters and *emerging* and/or *potential* clusters (Chapman, MacKinnon et al., 2004; Tödtling and Trippl, 2004; Dalum, Pedersen et al., 2005; Wolter, 2005; Bergman, 2006).

In this paper, we identify some of the conceptual and practical issues that arise in the conduct of regional cluster studies that focus on joint university-industry strengths as a basis for policy action. Rather than frame our arguments in the hypothetical, we ground the discussion in a comparison of the methodologies of two recent applied cluster studies in the U.S. The first is an analysis commissioned by the Appalachian Regional Commission (ARC) that sought to identify technology-based clusters across the ARC service area, an expansive territory that extends from northeastern Mississippi to central New York State, touching parts of thirteen states in total. The second initiative, an effort pushed by university leaders but embraced and facilitated by a regional economic development marketing organization, focused on identifying current and potential clusters in a single region with a significant existing compliment of research universities and high technology businesses: the Research Triangle Park (RTP) region of North Carolina.

Both studies are useful cases to examine for two reasons. First, each is an example of "best practice" in some sense. The ARC study is one of the most extensive analyses of regional clusters in the U.S. in terms of the scope and level of detail in its geographic coverage and its diverse array of included indicators. The RTP project follows on the highly publicized five-region Clusters of Innovation initiative spearheaded by the U.S. Council on Competitiveness. The RTP study also sought to be model for cluster-based economic development planning in other regions of North Carolina. Second, the two studies are similar in that both sought to detect areas of existing or potential university-industry strength as sources of competitive advantage and future growth. Yet their differences in objectives, scope, design and methods help highlight some of the key strengths and weaknesses of industry cluster analysis as a tool for economic development planning, particularly as it relates to regional innovation. A comparison of the two methodologies also exposes some of the "fuzziness" inherent the cluster concept as applied in practice.

The paper is organized as follows. Sections 2 and 3 briefly summarize the ARC and RTP projects in turn. We discuss each study's research design and approach to measurement, focusing specifically on how clusters are defined, how real (or hoped-for) linkages between local industries and research universities are conceptualized and measured, and how the studies are now being used to inform policy making. Section 4 then compares and evaluates the studies, focusing on two major issues: first, the degree to which each study can, *in principle*, inform typical regional economic development challenges in industrialized countries given its specific objectives and assumptions; and, second, whether each study approach is likely, *in practice*, to generate valid findings given definitional, data, and other empirical concerns. Section V concludes the paper with a brief summary and discussion of guides for regional development officials considering undertaking similar cluster initiatives.

2 The ARC Study

In late 2000 the Appalachian Regional Commission commissioned an inventory of high technology clusters Appalachian region. The analysis, which was released in 2002 (Feser, Goldstein et al., 2002), relied heavily on secondary data since the aim was to systematically inventory R&D, innovation, and technology specializations across all counties in the ARC service area—a total of 406 counties at that time—together with a buffer zone of border counties. The project examined technology-related assets within and near the region from two perspectives: the industrial base, defined as technology-based goods and services production and employment; and the knowledge base, defined as knowledge creating institutions and programs. Figure 1 summarizes the conceptual framework: technology clusters were defined as "the overlap between the industry and the knowledge/innovation strengths" (Feser, Goldstein et al., p. 7). Multiple sources of evidence were assembled for each of the two dimensions "given the myriad plausible ways that high-tech activity might be defined, measured (in terms of quantity), and assessed (in terms of quality)" (p. 7). In this scheme, identified clusters are places where a moderately to highly sophisticated knowledge infrastructure is joined with a substantial related industrial base.

[Figure 1 near here]

Measurement of the High-Technology Industrial Base

Rather than utilize a single definition and measure of high-technology industrial activity, the study characterized Appalachia's industrial base by synthesizing findings generated with two kinds of related information: 1) the location of employment in eight high-technology value chains; and 2) the location of science and engineering workers in thirteen occupational categories that map to the eight value chains. In the case of value chain employment, county-level data and a measure of spatial autocorrelation—the *G* statistic—was used to identify unique multi-county areas where technology-related activity is disproportionately clustered. The same approach was not possible for the occupation analysis since data on science and engineering workers were available only for metropolitan areas. Instead, the study used location quotients. Because of the varying geographic units for which data could be obtained (e.g., zip codes, counties, metro areas), the study relied on graphic overlays in a GIS system to facilitate visual identification of those sub-regions within and along the border of Appalachia where technology-related activity is especially pronounced.

The value chains are technology-intensive Standard Industrial Classification (SIC) system sectors classified into eight groups based on a detailed analysis of national input-output patterns. Therefore, they represent technology-intensive buyer-supplier chains in the U.S. economy as a whole, not Appalachia. Each is comprised of between eight and thirty diverse four-digit SIC codes. The chains, which are not mutually exclusive since sectors tend to be linked to multiple industries, form the core around which the rest of the study is organized: they serve as a common reference classification of high technology activity. Concordances between the chains and all other variable classifications (e.g., university disciplines, science and engineering occupations, industry utility patents, etc.) are what make possible a single consistent set of functional and geographic technology overlays from which spatial clusters could be identified.

The county employment data used in the study were from the confidential unsuppressed Unemployment Insurance Data Base (UDB) of the U.S. Bureau of Labor Statistics, obtained with special permission. The UDB data, which contain employment and wage figures by establishment for all fifty states, permitted a fine-grained look at employment patterns even in very small counties. The metropolitan-level occupational employment data were from the U.S. Bureau of Labor Statistics' Occupational Employment Statistics (OES) series. Fifty-six specific science, engineering, and engineering technician occupations were selected from the 709 occupations reported in the 1999 OES release and organized into thirteen substantive groups that roughly paralleled, though were more detailed, than the eight value chain categories. A concordance between the thirteen categories and the eight value chains was then established.[1]

Measurement of the Knowledge Infrastructure Base

The study defined Appalachia's knowledge infrastructure as comprised of two major components: organizations conducting scientific research and applied innovation and the network of universities and colleges engaged in developing the region's human capital base. (In the case of major research universities, the two components came together.) The definition implied that Appalachia's science and innovation assets are principally based in eighteen research universities and a limited number of non-academic research institutions (such as federal government laboratories), non-profit R&D organizations, state-sponsored technology agencies, and private sector businesses engaged in innovation. The region's higher education network consists of over 250 universities, colleges, and community colleges offering degree programs and specialized training in fifteen science and engineering-related fields. In 1997/8, four-year institutions in the region conferred over 23,600 science and engineering degrees while two-year colleges and institutes granted an additional 12,200 degrees. Many more students obtained relevant training at Appalachian community colleges without earning degrees.

There are eleven research universities located in ARC territory and an additional six situated adjacent to or very nearby the ARC boundary. The six adjacent schools were included on the assumption that their close spatial proximity yields a high potential spillover effect into the region.[2] One additional institution not classified as a doctoral university (extensive) by the Carnegie Foundation was also added because of its uncommonly strong technology focus and close proximity to the ARC service area.[3]

The study used three measures to characterize university competitiveness or strength by discipline: 1) perceived faculty quality as judged by peers in 1995; 2) external research funding receipts in 1991 and 1999; and 3) the number of full-time graduate students enrolled in 1991 and 1999. The measures were converted into national rankings and a concordance between the set of value chain categories and the disciplines was created in order to establish a common scale for combining the disparate dimensions of research strength. The rankings were then averaged across the disciplines within each technology area. For example, the study defined Cornell University's rank for sponsored research relevant to the chemicals and plastics value chain as the arithmetic average of its national ranks for chemical engineering, materials engineering, and chemistry.

Given the rankings on the three indicators, Tier 1 universities were defined as those institutions with an average rank in the U.S. top 20 for at least two out of the three measures. Tier 2 schools were defined as those with: a) an average rank in the U.S. top 20 for research funding or faculty quality; b) an average rank in the U.S. top 40 for all three measures; or c) an average rank in the

U.S. top 20 for number of graduate students and a rank in the U.S. top 40 for either (or both) faculty quality or research funding. The criteria effectively considered sponsored research and faculty quality as the leading barometer of a university's research capacity and output.

The study documented four additional major indicators of R&D and/or educational capital in addition to universities. First, it identified all major non-academic research institutions located in the region (eighteen in total), documenting funding levels for those that conducted defense-related research. Second, as a rough indicator of private sector innovation activity, the study used data from the U.S. Patent and Trademark Office (USPTO) to measure patenting in ten technology sectors that roughly corresponded to the eight value chain categories. Both location quotients and *G* statistics were used to identify geographic areas of patent clustering. Third, the project documented federal innovation funding program winners in the ARC region in all technology areas that matched to the value chains, mapping the winners by zip code.[4] Finally, the study used the U.S. Department of Education's Integrated Postsecondary Education Data System (IPEDS) to track recent degrees granted in all postsecondary educational institutions in the region. The highly detailed degree data were aggregated into fifteen disciplinary/program areas that paralleled the National Science Foundation discipline classification and then mapped to the eight industry value chains.

Joining the Information: Finding ARC's Technology Clusters

The final step in the methodology was to assemble the multiple variables specifying joint industrial and innovative strengths for each of the eight technology areas into a single GIS database. The indicators included technology intensive value chain employment by county (*G* statistics and location quotients), science and engineering occupational employment by metro area (location quotients), Tier 1 and 2 research universities by location (ranking), technology-related utility patent grants by county (*G* statistic and location quotients), innovation grant award winners by county, and degree completions. A series of maps revealed sub-regions where both high technology industry and related R&D and innovation activity were in evidence as of the late 1990s. Figure 2 is an example of the mapped output for a single technology category: industrial machinery. The mapped data were also summarized using a simple index useful for analyzing broad patterns in technology clustering across the region.

[Figure 2 near here]

Unlike the RTP study described in the next section, the ARC cluster analysis was not intended to inform a single specific policy initiative. Instead, its aim was to inventory technology clusters for subsequent use by ARC and local, regional and state economic development organizations in the region. The study showed that many of Appalachia's clusters are in traditional manufacturing (chemicals, motor vehicles, and industrial machinery), that the region's industrial base is oriented toward high tech industries of moderate technology intensity, and that the joint spatial clustering of business and innovation/R&D in some very high tech sectors (e.g., information technology, software, and aerospace) is quite limited. While some Appalachian universities boast significant existing or emerging R&D strengths in science and engineering disciplines, often those universities are not located nearby significant concentrations of industrial employment in related sectors. Likewise, while Appalachia has its share of federal laboratories and other non-university R&D institutions, they are not always spatially coincident with the technology-oriented industrial base. Indeed, the analysis found that a great many of the region's clusters are located on its periphery, making Appalachia's high-tech growth prospects heavily dependent on spillover (or "spread") effects from neighboring cities and metropolitan areas.

3 The Research Triangle Cluster Study

The RTP region study originated with a project organized by the Council on Competitiveness, a non-profit organization formed in 1986 to advocate strategies to strengthen U.S. competitiveness in the face of stiffening foreign competition. Historically the Council viewed U.S. competitiveness issues through a national lens. However, in the late 1990s, influenced heavily by the ideas of Michael Porter, a member of the organization's Executive Board and an influential player in its genesis in the 1980s, the organization began to shift its focus to the regional scale. It came to see national innovation as contingent on regional innovation processes and the success of localized clusters:

> In healthy regions, competitiveness and innovation are concentrated in **clusters**, or interrelated industries, in which the region specializes. The nation's ability to produce high-value products and services that support high wage jobs depends on the creation and strengthening of these regional hubs of competitiveness and innovation (Porter, Monitor Group et al., 2001b, p. v)

In 2000 the Council began a multi-region cluster study that it called the "Clusters of Innovation Initiative." The project applied Porter's framework for analyzing clusters and regional competitiveness to five U.S. regions: Atlanta, Pittsburgh, the Research Triangle, San Diego and Wichita. The effort sought both to understand clusters in each individual region and to use the collective results to more rigorously test a variety of hypotheses about "how innovative capacity is built" (Porter, Monitor Group et al., 2001b, p. 1). Analysis for each of the cases was based heavily on data from the Cluster Mapping Project at the Harvard Institute for Strategy and Competitiveness, supplemented with surveys and interviews in the host regions. Despite the Cluster Mapping Project's claim to be "perhaps the most detailed data set related to economic composition and performance ever compiled," it is essentially a set of national industry cluster definitions (mutually exclusive groups of SIC codes) matched to publicly available secondary data sources (*County Business Patterns*). The Clusters of Innovation Initiative documented trends in clusters in the study regions using the secondary employment data and then used interviews and survey-based information to help interpret those trends. Each of the five case reports follows a similar boilerplate. The executive summaries offer two major types of findings: first, general arguments regarding the role of clusters in regional economies and implications for policy and the role of government; and, second, empirical findings regarding basic economic indicators, industrial composition, innovation assets, and identified clusters.

The Council's RTP study (Porter, Monitor Group et al., 2001a) identified 14 existing and emerging clusters in the region, some traditional (e.g., textiles, tobacco, heavy machinery) and some technology-oriented (e.g., communications equipment). The pharmaceuticals/biotechnology and communications equipment clusters receive particular emphasis. The study called attention to weaknesses in the region's infrastructure, primary and secondary education systems, technology commercialization capacity, lack of industrial diversity, branch plant dominance, lack of collaboration among companies in different clusters, and high degree of interjurisdictional competition (i.e., absence of regional cooperation). One of its major recommendations was that regional officials seek to build a consensus around a shared, innovation-oriented strategy for regional economic development.

Regional government, academic, and business leaders were highly receptive to implementing the suggestions of the Council's report, in large part due to the leadership of the University of North Carolina. The UNC System president, Molly Corbett Broad, was a member of the Council on Competitiveness Executive Committee at the time, and she actively raised the financial and political support for the Triangle's inclusion as one of the Clusters of Innovation case regions. In 2002, regional leaders formed a 37-member Future Cluster Competitiveness Task Force, chaired by former North Carolina governor Jim Hunt, and staffed by the Research Triangle Regional Partnership (RTRP), the region's state-designated economic development marketing organization. The Task Force set to work developing an economic development plan, relying heavily on planning and facilitation support from the Small Business Technology Development Council (SBTDC), a unit of the University of North Carolina; consulting support from RTI International, a non-profit research organization formed in 1959 with the establishment of the Research Triangle Park; research assistance from the Office of Economic Development at the University of North

Carolina at Chapel Hill; and staff support from RTRP. RTRP is now directing the implementation of the plan, with continued support from SBTDC.

[Table 1 near here]

Table 1 summarizes the major elements of the RTP cluster study. Associated with each element is a document, culminating with the five year strategic plan: *Staying on Top: Winning the Job Wars of the Future* (RTRP, 2004). At the heart of the cluster analysis was an R&D inventory and technology growth opportunity study conducted by RTI International (RTI, 2003a). Eight technology areas identified by RTI, along with two rural-based industrial clusters highlighted in a study conducted by UNC's Office of Economic Development (OED) (Luger, Stewart et al., 2003), became the "clusters" prioritized in the strategic plan. The RTI clusters and OED clusters are fundamentally different. The former are essentially technology-related R&D fields that have the greatest potential to generate new and existing firm growth in the region as they develop. Some of the RTI technology areas dovetail with existing industry strengths in the region (e.g., pharmaceuticals, advanced medical care), but they were identified principally based on an assessment of R&D opportunities. The OED clusters are more traditionally measured as local concentrations of interdependent industries that are predicted to grow over the next ten to twenty years. Table 2 lists the ten clusters featured in the strategic plan. The next two sections provide a brief overview of the RTI and OED methodologies.

[Table 2 near here]

Inventorying the Region's R&D Assets and Growth Opportunities

The RTI inventory and growth study sought to "provide information on the research and development (R&D) strengths of the Research Triangle region and to identify opportunities for capitalizing on those strengths in 'hot technology' areas over the next 10-20 years" (RTI, 2003a, p. 1). Figure 3 documents the major steps in the analysis along with key information sources and variables.

[Figure 3 near here]

The RTI team began by using mostly secondary data on R&D spending, facilities, and technology transfer from universities, non-profit labs, and federal labs to create an initial inventory of research strengths in the region. Actual industrial R&D spending and activity in the Triangle received little attention at this stage, in large measure because of the absence of appropriate secondary data. RTI used interviews of key informants—senior university researchers, technology transfer staff, and local venture capitalists—to refine the initial list to 30 key technology areas. Two to six specific growth opportunities within each of the 30 areas were then identified based on information from existing industry roadmaps, technology needs assessment studies, government program documents, and science and technology forecasts. RTI's assessment of the research and market opportunities across the 30 areas is extraordinarily detailed, constituting 150 pages of the 179-page final report. With the help of a panel of experts, RTI also developed a rough concordance of the 30 areas to the 14 clusters identified in the Council's 2002 Research Triangle study. The concordance includes a four-level qualitative scoring of the "relevance" of the technology areas to each cluster.

The RTI team used the two major pieces of accumulated evidence—the multiple identified growth opportunities within the 30 technology areas and the mapping of those technology areas to the 2002 Council study findings—to recommend that the region focus its energy and resources on eight technology areas that were judged to have the greatest market potential, best fit with existing university and industry research strengths, highest relevance for multiple clusters, good funding support from government and/or private sector sources, and maximum resilience to offshore competition. In short, the eight areas are new and *emerging* technologies that RTI believes have the most potential to drive private sector employment opportunities in the Triangle over the next two decades. By design, they are not necessarily major *existing* sources of regional employment; they are cutting edge technologies and research areas that may drive emerging markets.

Identifying Cluster Targets of Opportunity

The OED study sought to complement the R&D inventory by focusing on industrial activity (Luger, Stewart et al., 2003). The investigation applied a set of national benchmark cluster definitions to an extended 19-county area and included separate analyses for core metro counties in the region, non core metro counties (roughly interpreted as suburban areas), and non-metro or rural counties.[5] The OED team argued that "different types of clusters make sense in different types of locations, and different parts of clusters are appropriate in different places" (Luger, Stewart et al., 2003, p. 2). Using employment data for two time periods (1996-99 and 1999-02), simple measures of absolute and relative size (the latter a location quotient), and separate benchmarks for clusters as a whole and their technology-based components, the study identified 11 "appropriate target clusters" for the region, distinguishing the relevance of each for different sub-areas. Two major criteria filtered the targets from a total of 14 benchmarks: 1) "indications of competitive local advantage, either by a sizable presence already in the region, or rapid changes in location quotient"; and 2) comprising "businesses that are adding jobs…or at least not losing employment if the businesses are becoming more productive" (p. 19).

The OED analysis highlighted several traditional industry clusters with growth potential in rural areas of the region, including food products, chemicals and plastics, motor vehicle parts and assembly, industrial machinery, and transportation and logistics. In the end, only two target clusters—logistics and distribution and vehicle component parts—were eventually included in the strategic plan. Even then, the plan makes clear that the two OED-identified clusters are of secondary importance, included primarily to address concerns about the future of the region's rural areas:

> RTI identified eight areas that hold the highest potential for boosting economic growth in the near term…These eight draw on the region's most competitive and innovative R&D assets. They represent the region's best opportunities for strong and sustainable job creation and business investment and growth…Although universities and businesses will continue to pursue growth opportunities in all of the areas identified by RTI, the institutional partners working on this initiative will collaborate to focus new resources on these eight growth priorities…In addition, the region will focus on two additional industry sectors that are important for job creation in more rural parts of the region: vehicle component parts and logistics and distribution (p. 9).

Unlike is the case for the eight technology clusters, there is no discussion in the plan of specific growth opportunities and strengths within the vehicle component parts and logistics and distribution clusters. The two clusters receive little more than a mention.

The Regional Competitiveness Plan

Three other projects in addition to the RTI and OED analyses informed the development of strategic plan: a series of focus groups organized for each of the eight technology areas (RTI, 2003b); a brief assessment of the region's life sciences industry (Pellerito, 2003); and six working groups made up of a diverse selection of business, academic and government officials and leaders. The focus groups and life sciences assessment did not influence the cluster identification effort as much as they supplied ideas on how the region might promote the growth of selected clusters. The working groups, whose activities were facilitated by SBTDC, developed the specific strategies and action steps that eventually fed into the strategic plan.

Staying on Top outlines five strategies and 30 action steps to spur job creation around the ten identified clusters. The strategies include: 1) organizing economic development efforts around the clusters (including creation of cluster support networks, development of a regional workforce coordination strategies, continuing research on emerging cluster opportunities); 2) targeted business creation, recruitment and retention (e.g., marketing, entrepreneurship support); 3) linking of higher education to economic development (e.g., one-stop points of contact to university resources, higher education rapid response teams organized around each cluster); 4) rural prosperity initiatives (most significantly, a rural industrial park for businesses in targeted clusters labeled a "mini-hub"); and 5) creation of "agile leadership networks" to respond to market shifts and opportunities. The plan calls for raising $5 million over five years to support an effort to "generate 100,000 new jobs and increase employment in all 13 counties of the Research Triangle Region" (RTRP, 2004, p. 4).

4 Lessons for Technology-Focused Cluster Studies

What can be learned from the ARC and RTP projects that might inform the conduct of similar studies in other regions that seek to formulate development strategies around university-industry clusters? At the heart of this question are two major issues. First, how appropriate are the objectives of the studies, given what we know about the relationship between university research activities, private sector R&D, business competitiveness, and industrial growth? Underlying the objectives are implicit or explicit definitions of what clusters are and how they drive regional economic outcomes. Second, if the objectives of each project are taken at face value, how valid is the actual empirical work? Using the language of research design, are there internal validity threats—factors that drive a wedge between study objectives and empirical results—that may ultimately lead to the formation and adoption of misleading policy actions or the neglect of issues essential to the strengthening of regional innovation systems? The validity threats may derive from data constraints, use of poor measures, resource constraints, or data collection procedures that realistically may or may not be surmountable. The two issues might be reduced to the following: do we have the right objectives and can we legitimately meet those objectives with the tools at our disposal?

Appropriate Objectives?

The ARC study defines technology clusters as locations—specified as counties or multi-county areas—where there is current relative concentration of industrial activity in an identified high technology value chain *as well as* demonstrated university research and training strength in disciplines related to that value chain. From a policy standpoint, the study assumes that areas of joint university-industry specialization represent the appropriate building blocks of technology-based economic development. Moreover, specializations are detected relative to national norms, not local benchmarks. A university specialization in a given discipline is based on its ranking against universities nationwide, not institutions within the given location or broader ARC region. Likewise, industrial specializations based on employment numbers and patent counts are identified from national share comparisons. The best academic program in the region is not a specialization in the ARC study if it is not highly ranked nationwide.

Similarly, a large volume of local activity in value chain *i* is an industrial concentration not because it is large locally, but because it is an outlier in a national spatial distribution. In these respects, the ARC study is consistent with Porter's diamond model and its emphasis on corporate activity and *existing* competitive advantage.

The RTP project adopted a much less conventional approach. Clusters in the RTP project scheme are hybrids between current and potential economic strengths. The basis of the current strength for most of the identified clusters is academic rather than corporate. That is, identified current strength is found mostly in strong university disciplines, productive scholars, projected national research priorities on which area universities believe they can capitalize, locally-based federal laboratories, and perhaps some evidence of private sector entrepreneurial activity. Implicit in the model is that the academic research strengths and cutting-edge science will translate to new economic engines in the future (the potential strengths), either via connections to existing technology industries or through university spin-offs or independent new business creation. That is clear enough in the strategic plan, which lists the key regional resources for each of the eight core clusters.[6] Aside from the pharmaceuticals cluster, which represents an existing and widely-recognized industrial strength in the region, most of the resource compendia highlight academic or non-profit research capabilities before mentioning any corporate presence, much less private sector R&D. In essence, RTP has identified areas where it is most likely to be a science and innovation leader and is gambling that with the right strategies it can turn that innovation into job growth in offices and factories, not just federal laboratories, universities, and colleges.

The validity of the objectives of each study varies depending on the policy concerns and context at hand. The ARC study suffers from what is, in one respect, a major weakness: identifying current clusters means focusing on areas of industrial and academic strength that may very well be in decline, or at least have achieved their peak. Indeed, the elements of the RTP project that are most similar to the ARC effort, namely the original Triangle region cluster analysis by the Council on Competitiveness and the benchmark industry cluster study by OED, identified some Triangle industries that are not likely to be the source of significant job growth over the next decades (e.g., textiles, heavy machinery, tobacco). The ARC study found that most of Appalachia's technology clusters are in chemicals and plastics, industrial machinery, motor vehicles, and household appliances, not exactly industries that are projected to expand rapidly in the U.S. or the region.

On the other hand, the ARC study objectives potentially produce results that can effectively inform two key areas of economic development practice:

business retention activities focused on industrial modernization and workforce development concerned with transitioning workers from declining sectors. Those are both areas that are especially important for regions with a history in heavy industry and a modest complement of nationally competitive research institutions and major federal laboratories.

The RTP study's key strength is its emphasis on future growth and the fact that it builds on what is arguably the region's true locally-based competitive advantage: its three world class universities. The RTP approach addresses a major limitation of much applied industry cluster analysis head-on, namely, its tendency to document past industrial successes rather than future sources of job growth. Among the RTP project's weaknesses are that it offers precious little understanding of the needs of existing industry, aside from those of a few selected sectors, and that it adopts a very limited view of human capital formation as a foundation of the region's competitiveness. One of the more consistent findings of the literature on the impact of universities on regional economies is the role of the university as educator of the next-generation workforce (Goldstein and Renault, 2004; Goldstein and Drucker, 2005). In focusing its economic development efforts around eight cutting edge areas of science, the RTP project implicitly downplays the importance of developing more basic training and curricular programs that can serve the current mix of businesses and jobs in the region more effectively. Admittedly, there are other initiatives underway in North Carolina to address university and college curricula issues in the context of workforce preparation, but they receive scant mention in what is labeled as the official "Competitiveness Plan for the Research Triangle Region."

There are two other issues related to each study's objectives that deserve consideration. The first is the nature of the connection between universities and innovation-led industry growth. It is hard to imagine that the design of the RTP project and resulting strategic plan were not influenced by local observation of the tight connections between the region's universities and its pharmaceuticals and biotechnology sectors. The Triangle is one of few legitimate biotechnology hubs in the U.S. (Cortright and Mayer, 2002), and the close linkages between the academy and the private sector in biotechnology are well-documented. The vision of university-industry collaborative science, small business entrepreneurship, university spin-offs, and technology transfer that characterizes the biotechnology industry permeates much of the RTP's plan. How likely is that vision—a kind of nirvana of university-industry synergies—to extend to other areas of technology, such as pervasive computing, analytical instrumentation, informatics, and nanotechnology? The weight of evidence to date is mixed. While authors like Mowery and Sampat (2005) believe such synergies are increasing, they are hard pressed to find clear empirical evidence of it in the U.S. Betts and Lee (Betts and Lee, 2004) argue that the role universities play in supporting the growth of technology clusters is overstated, and a careful historical analysis of efforts to translate the Silicon Valley model to other regions cautions against uni-dimensional explanations of the link between university research prowess and industrial growth (Leslie and Kargon, 1996). The conceptualized nexus between universities and industries in the ARC study is problematic as well, if current areas of joint university-industry specialization reflect a past economic history where universities acted as last-resort substitutes for low levels of technical capability in local firms (Rosenberg and Nelson, 1994). Clearly, whether and how university-businesses connections lead to the formation of new regional industries is not obvious. It remains a pressing research topic in the field of regional development.

The second issue relates to cluster policy implementation and its likely success. One might make a case that the RTP study, despite some of the drawbacks noted above, conceptualizes clusters in a manner best suited to what might be realistically achieved from a policy standpoint. There is an interesting paradox in what might be described as "industry cluster practice." On the one hand, many development officials are most interested in how cluster ideas might be used to promote the growth of next-generation industries, that is, clusters that do not currently exist in any sense of critical mass. On the other hand, most academics and cluster consultants argue clusters cannot be built from scratch because of the overwhelming dominance of market imperatives over which policy makers have little control (Ketels, 2004,Porter, 2003). The RTP model sees the region's future primarily in its science base. That base is strengthened with continued investments in university programs and laboratories, along with other relatively modest entrepreneurship support initiatives (e.g., incubators, technology transfer, R&D tax incentives, and marketing). Building a science base, particularly in higher education, is something that the public sector has proven it can do reasonably well. The strategy has the additional and not insignificant advantage of a ready external funding source: federal research dollars. A cluster strategy that is tilted toward the university's role may or may not generate thousands of new private sector jobs, but it is certainly capable of supporting the development of quality educational institutions and programs which have their own public interest benefits. The woeful record of strategies that seek to influence the behavior of businesses directly may indeed favor an academic science-led cluster approach, other things equal.

Industry Cluster Empirics

The discussion above presumes the studies have the right analytical methods and data to produce findings that satisfy their stated objectives. In actuality, there are a number of reasons to interpret and apply the results of applied industry cluster analysis very cautiously. Selected similarities and differences in the approaches of the ARC and RTP studies help to highlight some of the key empirical limitations of analysis aimed at identifying industry clusters in general, and university-industry clusters in particular.

Perhaps the most significant challenge facing any applied industry cluster study is data availability. This is especially true of studies focused on innovation activity or emerging markets. There are a wide variety of sources of data on industry trends, but they are often limited to employment series at the regional level. Employment is a reasonable measure of overall industry size from a labor market standpoint, but it is prone to offering a misleading view of the true presence, impact or growth of an industry in a region. Some industries are highly capital intensive, generating significant sales, and often regional interindustry linkages, with few employees. Other industries are growing in sales even as they cut employees. Substitutes for employment data are few. Readily available secondary data on industry R&D activities do not exist in the U.S. at the sub-state level, and even at the state level the data are not reliable since they are based on very small samples in surveys administered by the National Science Foundation. That is one reason why the RTP study did not attempt to systematically assess industrial innovation trends in the Triangle. The ARC study used patent data as a proxy measure of industrial innovation by sector in Appalachia. While better than ignoring private sector innovation entirely, patent data are not always a good barometer of the inputs in the research process. Industries also vary substantially in the degree to which they avail themselves of the patent system (Griliches, 1990).

The data challenge is not simply availability, but also whether or not available data series have meaningful levels of detail. Those levels may pertain to industry, geography, university and college disciplines, occupation, and areas of innovation. In the case of industry data, even the most disaggregated sectoral categories may be insufficient to distinguish important firm and market specializations. The problem is even more significant for trend data on university research. In the U.S., the National Science Foundation compiles university research expenditures by discipline, but the categories utilized are often too broad to document activity in the narrow scientific specialties that would provide the best hint of entrepreneurship opportunities. A given institution may have a scientific strength that is completely obscured if researchers from different disciplines are contributors. The artificial nature of conventional disciplinary classification schemes is only going to increase as research becomes more multi-disciplinary.

The ARC and RTP studies address data limitations in different ways. Since the objective of the ARC analysis—to document clustering across hundreds of counties—necessitated reliance on secondary data sources, the project utilized maximum sectoral and disciplinary detail and employed a variety of different measures of industrial and innovation activity. On the industry side, that meant requesting access to confidential data from the US Bureau of Labor Statistics. A special run of data was also requisitioned from the U.S. Patent and Trademark Office. The RTP study relied much more heavily on primary data collection, principally via review of the academic and trade literatures and interviews with key informants. Studying only a single region, the RTI technology assessment was able to utilize an iterative strategy whereby it produced an initial snapshot of regional academic, federal laboratory, and private non-profit research strengths; presented the assessment to local experts; revisited contested aspects of the assessment in a subsequent review; presented a revised snapshot for review; and so forth. The RTP study also substantially reduced the scale of its potential data problem by conceptualizing clusters as research strengths based mainly in academic science. That implied that local private sector R&D trends, which are much harder to objectively assess given the paucity of secondary data and the reluctance of firms to divulge their R&D expenditures, could be safely ignored.

Another major challenge for any assessment of real or potential academic-business linkages is the need to somehow map the scientific activity in the university to relevant business sectors, and vice versa. Both the ARC and RTP study utilize academic-industry concordances that substantially influence their findings. In the ARC study, eight national high technology value chains form the basis of the results; disciplines, patents by sectors, occupational employment, innovation awardees, and other variables are all assigned to one or more value chains. There is much that is a "leap of faith" in the mapping. First, the value chains themselves may or may not accurately distinguish technology specializations in the U.S. or Appalachia. Certainly eight chains appears to be a very small number for an economy as diverse as that of the U.S. The origin of the value chains in an objective analysis of input-output trends lends them credibility, but it is also possible that the relatively aggregated input-output data are in themselves insufficient for specifying related technology industries in proper detail. Second, the mapping of some of the indicators to the value chains involves an element of guesswork (e.g., chemistry but not biology is most likely to be relevant to the chemicals industry, etc.), as good data on the connections are not available. The RTI technology assessment used information from "experts" to map 30 initial technology areas to the Triangle industry clusters documented by the Council on Competitiveness. It is not evident that such an approach involved any less informed guesswork than in the case of the ARC study.

The sheer scope of the ARC study probably makes it more prone to either overlooking legitimate specializations that offer the best opportunities for technology-based economic development or failing to provide the level of detail necessary to formulate real development plans. For example, the study identified a "pharmaceuticals and medical technologies" cluster in Pittsburgh based on a revealed concentration of industry employment in the pharmaceuticals value chain, second tier rankings of Carnegie Mellon University (CMU) and the University of Pittsburgh (Pitt) in related health sciences disciplines, and a concentration of federal innovation research award winners in related health fields. While useful, more detailed information on the source of the overall pharmaceuticals and medical technologies specialization is required to formulate actionable plans.

We decided to investigate Pittsburgh more closely to discover the underlying strengths within the sectors and disciplines nominally assigned to the pharmaceuticals and medical technologies value chain. One such strengths is tissue engineering, the development and manipulation of laboratory-grown molecules, cells, tissues or organs to replace or support the function of defective or injured body. The discipline crosses several medical and technical specialties, including cell biology, molecular biology, biomaterial engineering, computer-assisted design, microscopic imaging, robotics engineering and scientific equipment manufacturing. The McGowan Institute for Regenerative Medicine (MIRM), established by the Pitt School of Medicine and the Pitt Medical Center health system, is considered one of the nation's most ambitious tissue engineering programs. In 2002 Congress established the National Tissue Engineering Center (NTEC) in Pittsburgh to facilitate related Department of Defense research among the top military and civilian scientists in the field. NTEC unites the clinical and research facilities of MIRM, Pitt, the Pitt Medical Center, research at CMU, and the Windber Research Institute with the U.S. Army's Institute for Surgical Research and the Walter Reed Army Medical Center. The region already recognizes the economic development potential of tissue engineering and the biosciences in general. Current development initiatives include the Pittsburgh Tissue Engineering Initiative (PTEI) and Pittsburgh Life Sciences Greenhouse (PLSG), the latter a public-private collaborative effort aimed at supporting the growth of regional life sciences companies in the areas of bioinformatics, bio-nanotechnology, diagnostics, medical devices, medical robotics, therapeutics, and tools and services. There are currently five biotech companies in a PLSG-run incubator space.

The Pittsburgh example illustrates a key difference between the ARC and RTP studies. Because of its heavily reliance on secondary data, the ARC cluster analysis searched for broadly defined and already well-developed clusters. Its overall findings are useful for gaining a sense of the overall pattern of technology-based economic activity in Appalachia, but more detail on the strength and vintage of specializations within identified clusters is needed in any particular region to formulate useful development strategies. Because a region has a lot of pharmaceuticals activity does not mean that more pharmaceuticals and biomedical employment or drugs research is the appropriate policy target. It is possible there are newer emerging areas of science and private sector growth that should be fostered within a broader health sciences cluster. By focusing on emerging science, the RTP study emphasizes innovation and new markets. Overall, the internal validity of the RTP study is stronger if informing specific policy options is the aim. Scientific specialties in the university are easier to assess than innovation strengths in industry and the small scope of the RTP study meant that it could use primary data collection to rectify the limitations of secondary data. That meant more detail and greater narrowing possible areas of development intervention.

Summary and Implications

In this paper we have compared two major recent industry cluster studies that focus on the intersection of industrial development and the regional science base. The different objectives and methodologies of the two projects illustrate some of the major challenges in applied industry cluster analysis as a basis for economic development policy and planning in general, and technology-based economic development in particular.

As with any analysis, the validity of applied cluster analyses hinge on the proper fit between objectives, methodology, and available data. Neither the ARC nor RTP study is a model that is appropriate for all circumstances. No cluster analysis should be undertaken without a clear articulation of the kinds of policies the results are intended to inform. With that articulation, many of the questions about the proper definition and measurement of clusters are resolved. It follows that some types of cluster analysis are not likely to be informative for certain kinds of regions. It is hard to imagine how the RTP study approach could be applied to a lagging region with a very modest science base, no top-notch universities, and an industrial structure dominated by branch plants conducting no localized R&D. In such cases, analysis of the fit between existing industrial concentrations, possible new growth industries (either via local growth or inward investment), and university and community college curricula is probably more useful since workforce development concerns are likely to well outweigh the potential for technology-based development. Likewise, the ARC study approach would be quite limited in its scope in an innovation-rich region like North Carolina's Research Triangle, where growth opportunities out of emerging scientific fields are a real possibility.

Both the ARC and RTP studies demonstrate how important it is to utilize primary and secondary data on industry and innovation strengths cautiously. The limitations of secondary data for cluster analysis are well documented. Excessively broad industry categories, aggregated disciplinary classification schemes, the absence of private sector R&D expenditure data, and the limited geography of many secondary data series make it hard to pinpoint narrower industrial and/or scientific specializations. Primary data collection, particularly via key informant interviews, offers a solution, but not one without its own risks. The strengths and weaknesses of qualitative methods in applied cluster analysis deserve much greater attention in the research literature. Too many applied analyses appeal to "experts" as the primary data source without explaining how such experts were identified, their advice solicited, and their opinions documented and analyzed.

Finally, both the ARC and RTP studies make assumptions about the importance of the regional science base for regional industry growth. In the case of the RTP study, in particular, there is much implicit faith that university-based science lays the groundwork for regional industries of the future. In an increasingly knowledge-based economy, that is not an assumption that policy officials find especially hard to swallow. However, while studies have found a connection between universities and regional economic growth, the preponderance of evidence suggests the link is modest and, most likely, based mainly in the traditional human capital function of higher education (Goldstein and Renault, 2004). It probably makes sense to foster the growth of academic science-based clusters as an element of a broader regional development plan in some instances, just not the sole element.

Notes

1. For example, chemists/chemical engineers and materials engineers/scientists occupations were matched to the chemicals and plastics value chain.
2. The eleven in the region are Carnegie-Mellon, Clemson, Cornell, Mississippi State, Ohio University (consolidated in the available data, but dominated by Ohio State University in Columbus), the Pennsylvania State University, the University of Alabama at Birmingham, the University of Pittsburgh, the

University of Tennessee, Virginia Tech, and West Virginia University. Adjacent universities are Auburn University, Georgia Institute of Technology, Emory University, the University of Georgia, and the University of Mississippi.

3. The additional institution is the University of Alabama at Huntsville.

4. The study documented grantees of the Small Business Innovation Research (SBIR) program, Small Business Technology Transfer (STTR) program, and Advanced Technologies Program (ATP).

5. The benchmark cluster definitions are from Feser and Koo (2000) and are derived using the same basic methodology as the high technology value chain clusters used in the ARC study (see also Feser and Bergman, 2000).

6. The two rural clusters (logistics/transportation and vehicle parts), which have a much stronger existing industrial foundation, receive no detailed attention outside of their mention in the list of ten target clusters.

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Table 1. Summary of RTP Study: Analytical Elements and Plan

Date	Title	Key Results/Findings	Contributor
1/2002	*Clusters of Innovation: Research Triangle*	Identified 14 industry clusters in the region, from agricultural products to heavy machinery to pharmaceuticals/biotechnology. Argued for support for existing clusters, upgrading traditional clusters and promoting growth opportunities in areas that cross-cut several clusters (e.g., in environmental sciences, biotechnology and information technology, telecommunications and medicine, and biotechnology and agribusiness).	Council on Competitiveness, Monitor Group and ontheFrontier
2/2003	*A Blueprint for Life Sciences Industry Growth in the Research Triangle Region*	Documents the size and potential growth of the region's life sciences industry. Developed primarily to influence debate over a biotechnology training initiative eventually funded by the NC legislature in mid-2003. Later listed as part of the RTP cluster project.	PMP Public Affairs Consulting
9/2003	*R&D Inventory and Analysis of Growth Opportunities in the Research Triangle Region*	Using mostly information from key informants and experts, identified 30 technology "strength areas" in the region based on R&D and innovation activity. From the 30, identified eight "overarching application areas" as representing best growth opportunities. Recommended region develop strategies to grow industry around the eight growth opportunities.	RTI International
10/2003	*Recommended Actions from Focus Groups*	Report of findings of focus groups around each of the eight application areas. A total of 68 people participated in the focus groups (not including project consultants or staff), some 33 from businesses in the region.	RTI International
11/2003	*Identifying "Targets of Opportunity": Competitive Clusters for RTP and its Sub-regions*	Using secondary data and benchmark cluster definitions identified major clusters in the 19 counties including and around the Triangle, in the three core metro counties of the region, in six non-core metro counties, and in ten non-metro counties. Recommended 13 possible targets for the region, including two that were eventually added to the eight proposed by RTI: motor vehicle components and transportation/shipping/logistics.	Office of Economic Development, University of North Carolina at Chapel Hill
3/2004	*Staying on Top: Winning the Job Wars of the Future*	Lays out a five-year, $5 million action research agenda "to generate 100,000 new jobs and increase employment in all 13 counties" of the region. Calls for five major strategies: "promote the growth of industry clusters where the region has a competitive advantage; use a balanced approach of targeted recruitment, global branding, business creation and existing business retention; integrate higher education into economic development efforts; develop creative, inclusive approaches to rural prosperity; create agile leadership networks to respond to market challenges, changes and opportunities" (p. 4).	Research Triangle Regional Partnership

Table 2. Clusters Prioritized in RTP Strategic Plan

Cluster	Study
Pharmaceuticals	RTI
Biological agents and infectious diseases	RTI
Agricultural biotechnology	RTI
Pervasive computing	RTI
Advanced medical care	RTI
Analytical instrumentation	RTI
Nanoscale technologies	RTI
Informatics	RTI
Vehicle component parts	OED
Logistics and distribution	OED

Source: RTRP (2004)

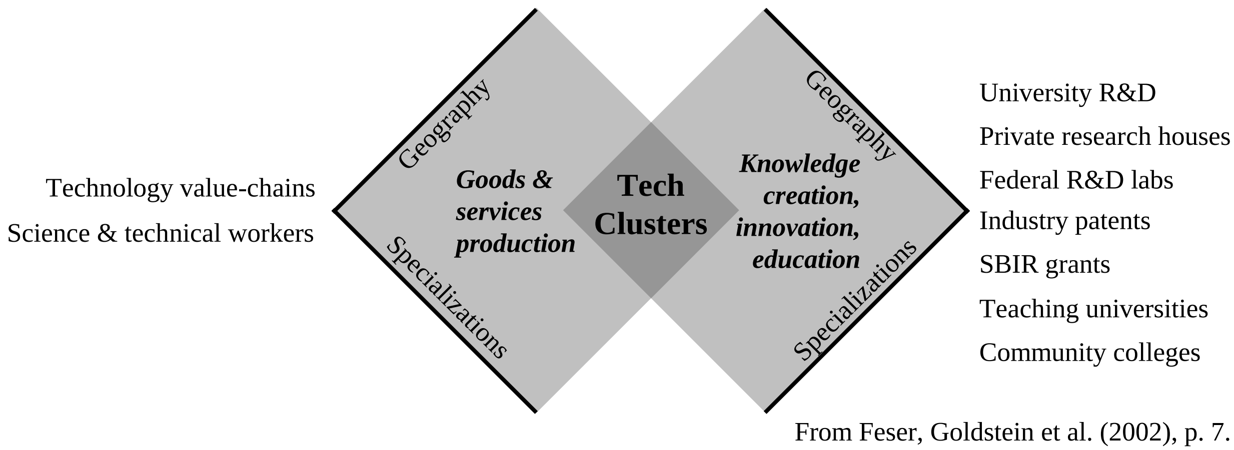


Figure 1. ARC study conceptual framework

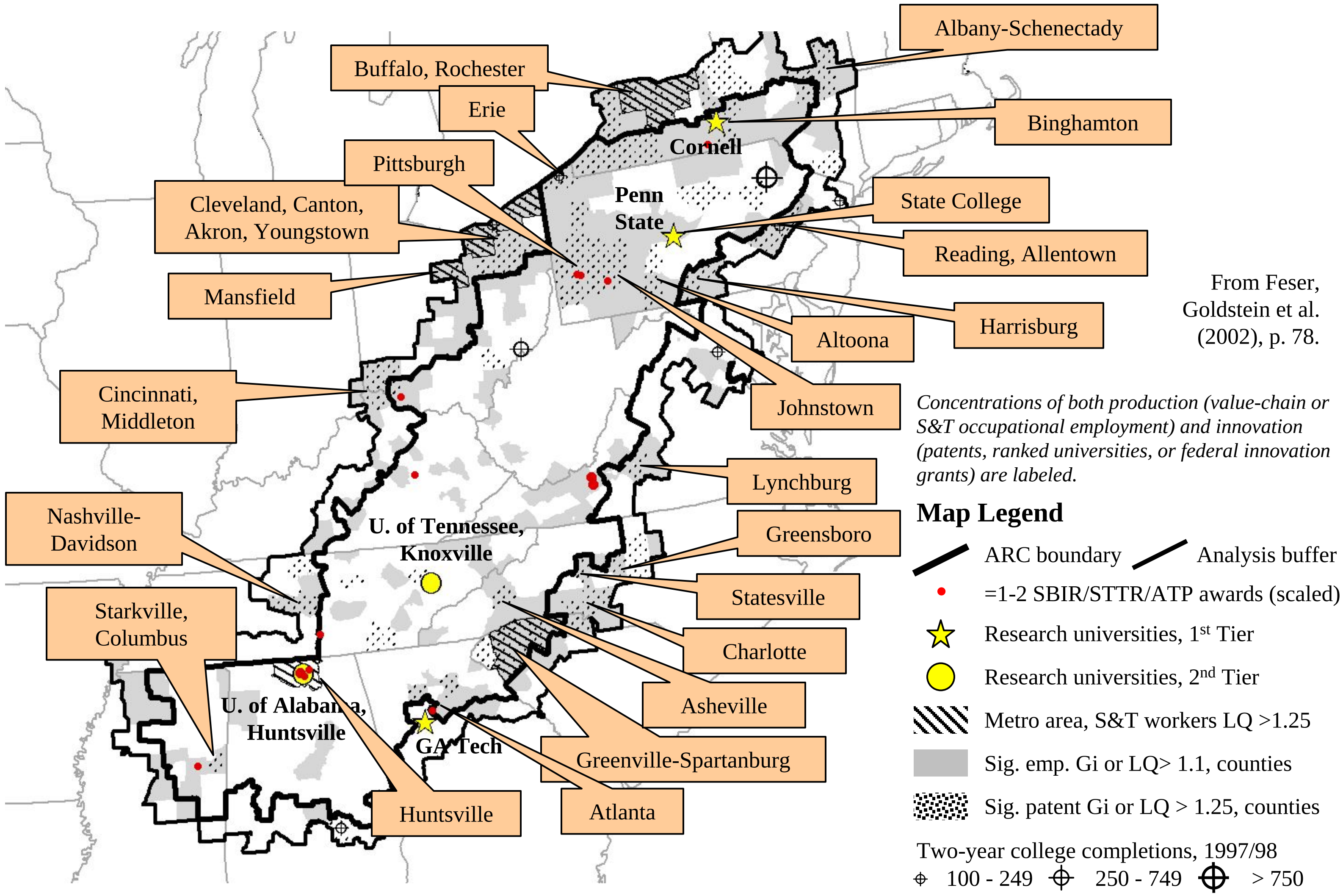
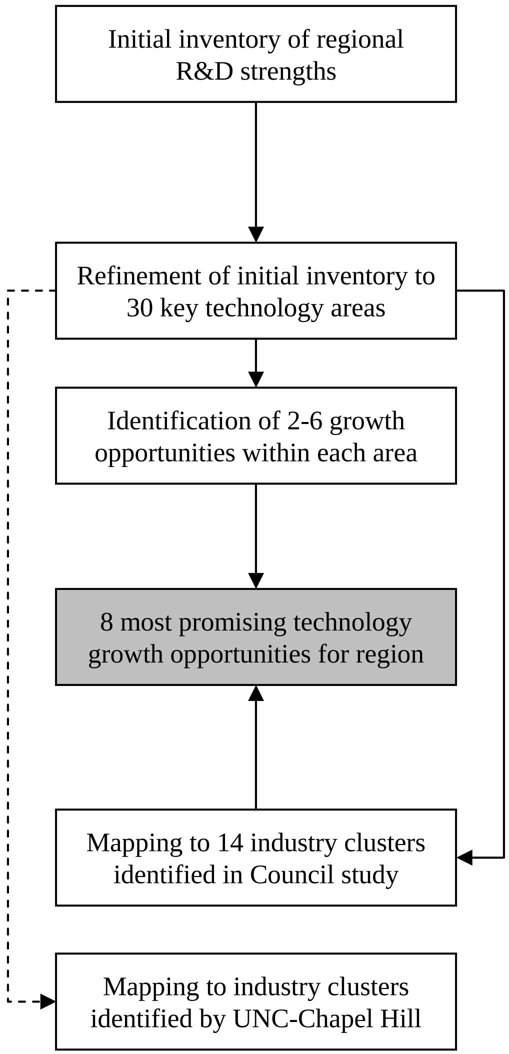


Figure 2. Example ARC study output: Industrial machinery technology clusters



Information sources	Variables/criteria
Universities Non-profit R&D labs Federal labs	Research funding, key researchers Invention disclosures, key innovators Tech transfer successes Scientific recognition (e.g., awards) Unique facilities Cuts across academic and corporate sectors
Senior researchers Tech transfer staff Local venture capitalists	Same as above
Industry roadmaps Tech needs assessments Government programs S&T forecasts	Technical needs Technology gaps Emerging markets Federal research priorities Industry research priorities
Accumulated sources	Market expansion potential Fit with academic research strengths Fit with regional industry clusters Potential of research or technology to cross-cut clusters Government and private sector funding trends Resilience to offshore competition
Panel of experts	Relevance of technologies to clusters

Figure 3. Overview of RTI growth opportunity study methodology