4 Technology Clusters in the ARC Region

By combining the information on the spatial concentration of industrial and occupational employment with data on R&D performers (research universities and federal labs), private sector innovative activity (as proxied by patents and participation in the SBIR/STTR/ATP programs), state technology services agencies, and educational infrastructure, we can identify Appalachian sub-regions characterized by joint industrial and research/innovation strength in specific technology areas. We call such sub-regions Appalachia's *technology clusters*. We explicitly define a cluster, in this case, as a localized concentration of joint industrial and innovative activity.[39] This section first outlines the standards we used to combine the results from multiple indicators to identify a reduced set of sub-regions. It then discusses general findings, policy implications, and avenues for further research.

4.1 Identifying Technology Clusters

To identify specific technology clusters, we require a means of evaluating the degree of overlap between geographic distributions of technology-related industry (including S&T workers) described in Section 2 and the information on leading university research programs, corporate patenting, SBIR/STTR/ATP grants, technology agencies, and higher education infrastructure analyzed in Section 3. Our first step was to use judgment to establish concordances between the set of technology-intensive value-chains described in Section 2 and the university R&D disciplines, degree completion disciplines, and S&T occupational categories utilized in Section 3. As one example, we matched the following disciplines and occupations to the chemicals and plastics value-chain: the chemical engineering, materials engineering, and chemistry R&D disciplines; the chemical engineering and technology; materials engineering and science degree completions disciplines; and the chemists/chemical engineers and materials engineers/scientists occupations. Table 17 reports the full set of technology area concordances.

39. There are many valid ways of defining industry clusters, with the appropriateness of a given definition depending primarily on research and policy concerns at hand. See the discussion in Bergman and Feser (1999).

To develop rankings of Appalachian universities by technology category rather than discipline, we then averaged the rankings across the disciplines *within* each technology area. For example, Cornell University's rank for sponsored research relevant to the chemicals and plastics industry is the arithmetic average of its ranks for chemical engineering, materials engineering, and chemistry. We produced rankings by technology area for three indicators: sponsored research funding, faculty quality, and number of enrolled graduate students.[40]

Given the rankings on the three indicators, we identified Tier 1 universities as those with an average rank in the U.S. top twenty for at least two out of the three measures. Tier 2 schools are those with: a) an average rank in the U.S. top twenty for research funding or faculty quality; b) an average rank in the U.S. top forty for all three measures; or c) an average rank in the U.S. top twenty for number of graduate students and a rank in the U.S. top forty for either (or both) faculty quality or research

Table 17
Technology area concordances

Technology area	University Disciplines	Degree Completions Disciplines	S&T Worker Categories
Chemicals and plastics	Chemical engineering, materials engineering, chemistry	Chemical engineering & technology; materials engineering and science	Chemists & chemical engineers; materials engineers & scientists
IT and instruments	Electrical engineering, mechanical engineering, materials engineering, physics, mathematics and statistics	Communications & computer sciences/technology; mechanical engineering, engineering physics & science, systems engineering	IT scientists, engineers, and programmers; electrical engineers & technicians
Industrial machinery	Mechanical engineering, industrial engineering, physics	Mechanical engineering, engineering physics & science, systems engineering; Industrial engineering & technology	Industrial & mechanical engineers & technicians
Motor vehicles	Electrical engineering, mechanical engineering, industrial engineering	Mechanical engineering, engineering physics & science, systems engineering; Industrial engineering & technology	Electrical engineers & technicians; industrial & mechanical engineers & technicians
Household appliances	Electrical engineering, mechanical engineering, industrial engineering	Mechanical engineering, engineering physics & science, systems engineering	Electrical engineers & technicians
Aerospace	Aerospace engineering, astronomy, geosciences, mathematics and statistics, computer science, physics	Aerospace engineering, aviation science & astrophysics; mathematics	Mathematicians, statisticians, and physicists
Communications services & software	Computer science, mathematics and statistics, geosciences	Communications & computer sciences/technology; mathematics	IT scientists, engineers, and programmers
Pharmaceuticals, medical technologies	Biological sciences, medical sciences, computer science	Biochemistry & biomedical engineering; botony, biology, bacteriology, & biotechnology; basic medical science	Biological scientists & technicians; medical scientists & engineers

Note: National Research Council discipline categories for faculty quality differed slightly from NSF categories, particularly in the medical and biological sciences. The NRC categories were aggregated to match the NSF classification to derive a uniform set of university disciplines.

40. Each measure indicates a different but complimentary dimension of university research competitiveness. In the absence of a compelling rationale favoring one dimension over the other, we elected to weight each indicator equally.

funding. Our criteria effectively consider sponsored research and faculty quality as the leading barometers of a university's research capacity and output. The results of the combined rankings are presented in Table 18.

University research strengths by technology area in or immediately adjacent to the ARC region are highly concentrated in a few institutions, namely Carnegie-Mellon, Cornell, Georgia Tech, and Penn State. Virginia Tech boasts Tier 1 programs in two technology areas, while Tier 2 programs are found at the University of Alabama at Huntsville, Clemson, and University of Tennessee at Knoxville. Eight of the eighteen universities in the study do not possess highly ranked research programs in any of the eight major technology areas by our criteria, though some have relatively strong individual disciplines or disciplines of emerging strength (as reported in Section 3).

To identify areas of joint industrial and innovative strength for each of the eight technology areas, we used a geographic information system (GIS) to overlay multiple variables: technology-intensive value chain employment by county, science and engineering occupational employment by metro area, Tier 1 and 2 research universities by city, technology-related utility patent grants by county, the location of state technology programs, and SBIR/STTR/ATP award winners by county. We also mapped total degree completions in related fields for both two-year and four-year institutions, although we focused on the presence of industry and innovative/R&D activity (rather than educational programs) as the formal criteria for identifying technology clusters. We then visually inspected the maps along

Table 18

University R&D strengths by technology area

1st and 2nd tier strengths based on U.S. rank

University	Chemicals & plastics	IT & instruments	Industrial machinery	Motor vehicles	Aerospace	Household appliances	Comm software & services	Pharm & med tech
U of Alabama at Birmingham								
U of Alabama at Huntsville			2	2		2		
Auburn U								
Carnegie Mellon U		2		1	2	1	2	2
Clemson U						2		
Cornell U	1	1	1	1	1	1	1	1
Emory U								2
GA Institute of Technology	1	1	1	1	2	1	2	
U of Georgia								
U of Kentucky								
Mississippi State U								
U of Mississippi								
Ohio U								
Pennsylvania State	1	1	1	1	2	1	2	
U of Pittsburgh								2
U of Tennessee at Knoxville			2					
Virginia Polytechnic Institute		2		1		1	2	
West Virginia U								

Note: Based on evaluation of national rank on three measures: research funding, faculty quality (based on peer rankings), and number of gradute students. Universities were ranked on sixteen disciplines. Each discipline was assigned to one or more of the eight technology categories (see Appendix Table 8). Average rankings across the disciplines in the given technology area were then used to determine the institution's overall rank on the given measure. Tier 1 schools are those with an average rank in the U.S. top 20 for at least two out of the three measures. Tier 2 schools are those with: a) an average rank in the U.S. top 20 for research expenditures or faculty quality; or 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 expenditures.

with a set of detailed cross-tabulations to detect a total of 100 sub-regions where both high tech industry and related R&D and innovation activity are in evidence. The results are summarized in Table 19 and Figures 36–43.

Our analysis indicated that heavy spatial concentrations of degree completions for four-year colleges and universities tend to coincide with the locations of major research universities. That is unsurprising given that the research universities are some of the largest educators in the region. Therefore, in Figures 36–43 we depict only degree completions for two-year higher education institutions. That has the advantage of emphasizing synergies between the universities and the key applied education and training role of community colleges. To maintain readability in the face of multiple data layers, Figures 36–43 do not depict the location of state technology agencies.

Table 19
Technology clusters in Appalachia

Chemicals & plastics	V	P	S	U	A	Notes
Buffalo, Rochester, NY	✓	✓	✓			
Ithaca and Binghamton, NY	✓	✓	✓	✓	✓	Cornell ranked as 1st tier in disciplines related to chemicals and plastics
Pittsburgh, PA	✓	✓			✓	
Albany-Schenectady, NY	✓	✓				
Newburgh, NY, PA	✓	✓	✓			
Cleveland-Canton, OH corridor	✓	✓	✓			
State College, PA	✓		✓	✓		
Reading/Allentown PA	✓	✓	✓			
Wheeling, WV	✓	✓			✓	
Charleston, WV	✓	✓	✓			Not a major strength of West Virginia University; Ohio University
Parkersburg, WV	✓	✓			✓	(all campuses) ranked 16th in research dollars in chemical engineering
Cincinnati, OH	✓	✓				
Washington, DC	✓	✓	✓			
Johnson City, TN	✓	✓			✓	
Asheville, NC	✓	✓				
Greenville-Spartanburg, SC	✓	✓	✓			
Chattanooga, TN	✓	✓				
Atlanta, GA	✓			✓		
Auburn, AL	✓	✓	✓			
Huntsville, Decatur, AL	✓		✓		✓	Chemical engineering an emergent strength at UA-Huntsville; UA-Huntsville ranked 6th in number of graduate students in industrial engineering

Motor vehicles & related	V	P	S	U	A	Notes
Rochester, NY	✓	✓	✓			
Syracuse, NY	✓	✓				
Binghamton, NY	✓	✓	✓	✓		
Scranton, PA	✓	✓				Large two-year college programs in related fields
Central Pennsylvania	✓	✓	✓	✓		
Reading, PA	✓	✓				Large two-year college programs in related fields
Altoona, PA	✓	✓				
Cleveland, Akron, OH	✓	✓	✓			
Mansfield, OH	✓		✓			
Cincinnati, OH	✓	✓				
Harrisburg, PA	✓	✓		✓		
Blacksburg, VA	✓					
Johnson City, TN	✓	✓				
Greenville-Spartanburg, SC	✓	✓	✓	✓		
Huntsville, AL	✓					UA-Huntsville ranked 6th in number of graduate students in industrial engineering; also a 2nd tier strength in disciplines related to motor vehicles

Table 19 continues next page

Table 19 *continued*

Technology clusters in Appalachia

Industrial Machinery	V	P	S	U	A	Notes
Buffalo, Rochester, NY	✓	✓	✓			
Erie, PA	✓	✓				
Albany-Schenectady, NY	✓	✓				
Binghamton, NY	✓	✓		✓		Cornell a 1st tier university in related disciplines
State College, PA	✓			✓		Penn State a 1st tier university in related disciplines
Reading, Allentown, PA	✓	✓				
Harrisburg, PA	✓	✓				
Pittsburgh, PA	✓	✓			✓	Carnegie-Mellon an emerging strength in mechanical and materials engineering
Northeastern Ohio	✓	✓	✓			
Mansfield, OH	✓	✓	✓			
Altoona, PA	✓	✓				
Johnstown, PA	✓	✓			✓	
Lynchburg, VA	✓	✓				Virginia Tech an emerging strength in electrical engineering
Cincinnati, Middleton, OH	✓	✓			✓	
Greensboro, NC	✓	✓				
Statesville, NC	✓	✓				
Charlotte, NC	✓	✓				
Nashville-Davidson, TN	✓	✓				
Asheville, NC	✓	✓				
Greenville-Spartanburg, SC	✓	✓	✓			
Atlanta	✓	✓		✓		Georgia Tech a 1st tier university in related disciplines
Huntsville, AL			✓	✓	✓	Weak industry employment but concentrated related occupations and 2nd tier university
Starkville, Columbus, MS	✓	✓			✓	

Information technology & instruments	V	P	S	U	A	Notes
Rochester, NY	✓	✓				Weak industry employment; large community college programs in related fields
Binghamton, NY	✓	✓	✓	✓	✓	Cornell ranked as 1st tier university in related disciplines
Poughkeepsie, NY	✓	✓				
State College, PA	✓	✓	✓	✓		
Washington, DC	✓		✓			Very large community college programs in related fields
Columbus, OH	✓	✓	✓		✓	Community college programs in related fields
Lynchburg-Blacksburg, VA	✓			✓	✓	Weak industry employment in Blacksburg; community college programs in related fields
Atlanta, GA	✓	✓	✓	✓	✓	Georgia Tech a first-tier university in related disciplines
Huntsville, AL	✓		✓			University of Alabama-Huntsville an emerging strength in computer science

Communications services & software	V	P	S	U	A	Notes
Ithaca, NY	✓	✓		✓	✓	Cornell a 1st tier strength in related disciplines
Albany-Schenectady, NY	✓	✓				
Newburgh-Poughkeepsie, NY	✓	✓				
State College, PA	✓			✓	✓	Penn State a 2nd tier strength
Harrisburg, PA	✓	✓				
Pittsburgh, PA	✓			✓	✓	CMU a 2nd tier strength; NSF Data Storage Center; Software Engineering Institute
Columbus, OH	✓		✓			Large two-year college programs in related fields
Washington, DC	✓	✓	✓			Large two-year college programs in related fields
Blacksburg, VA	✓			✓	✓	
Atlanta, GA	✓		✓	✓	✓	Georgia Tech a 2nd tier strength in related discipline; two-year college programs
Huntsville, AL	✓	✓	✓		✓	University of Alabama-Huntsville an emerging strength in computer science

Table 19 continues next page

Table 19 *continued*

Technology clusters in Appalachia

Aerospace	**V**	**P**	**S**	**U**	**A**	**Notes**
Erie, PA	✓	✓				
Elmira, Ithaca, NY	✓	✓		✓		Cornell a 1st tier strength in related disciplines
Cleveland, Akron, OH	✓	✓				
Pittsburgh, PA	✓	✓	✓	✓	✓	CMU a 2nd tier strength in related disciplines
Washington, DC	✓		✓			
Cincinnati, Middleton, OH	✓	✓				
Atlanta, GA	✓		✓	✓		Georgia Tech a 2nd tier strength in related disciplines
Manchester, TN	✓				✓	Nearby Arnold Air Force Base
Huntsville, AL	✓		✓	✓		University of Alabama-Huntsville an emerging strength in geosciences; Army Space and Missile Defense Command, Marshall Space Flight Center, Army Aviation and Missile Command, Army Redstone Technical Test Center, Army Redstone Missile Research Development and Engineering Center

Household appliances	**V**	**P**	**S**	**U**	**A**	**Notes**
Cleveland, Akron, OH	✓	✓				
Middleton, OH	✓	✓				
Greenville-Spartanburg, SC	✓			✓		
Huntsville, AL	✓		✓	✓		University of Alabama-Huntsville a 2nd tier strength in related disciplines

Pharmaceuticals & med technologies	**V**	**P**	**S**	**U**	**A**	**Notes**
Rochester, NY	✓	✓				
Ithaca, NY	✓			✓	✓	Cornell a 1st tier strength in related disciplines
Chenango County, NY	✓	✓				
Newburgh, NY	✓	✓				
Reading, PA	✓	✓				
Pittsburgh, PA	✓			✓	✓	CMU and Pitt 2nd tier strengths; Pitt an emerging strength biological sciences
Washington, DC	✓	✓	✓			
Cincinnati, OH	✓					
Birmingham, AL	✓	✓	✓		✓	

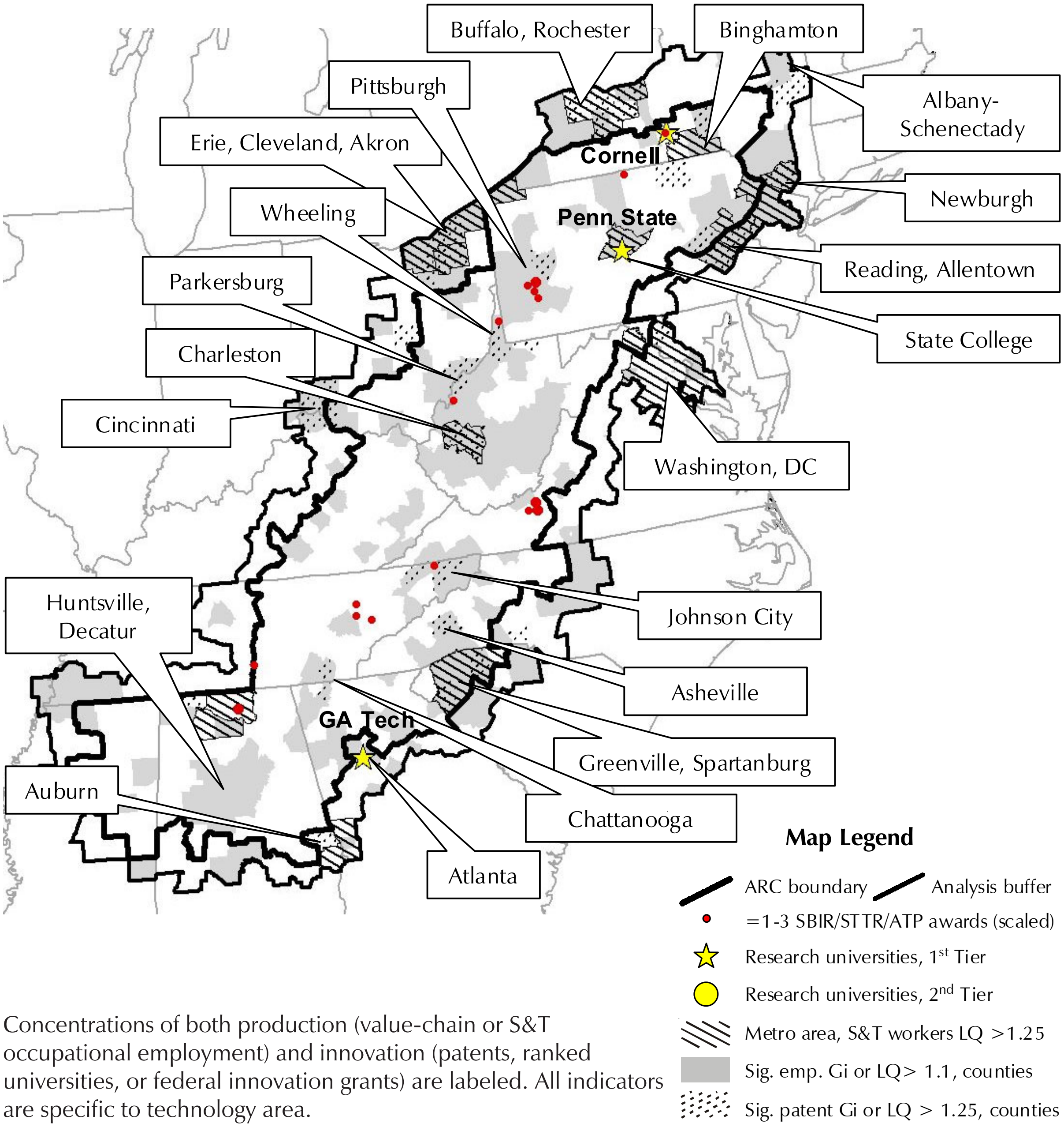
Legend and Notes: **V** = Concentration of employment in pertinent value-chain (either significant *G* or location quotient > 1.1, 1998). **P** = Concentration of patenting activity in related technology areas (either significant *G* or location quotient > 1.25, 1999). **S** = Concentration of scientists, engineers, and technicians in related fields (location quotient > 1.25; data available for metro areas only, 1999). **U** = Presence of a research university with related programs in 1st or 2nd tier based on national ranks (various years; see text for ranking criteria). **A** = One or more SBIR/STTR/ATP award winners in Fiscal Year 2000. Locations indicate general vicinity only. See text for data sources and general methodology.

The following results should be interpreted with care and especially with a mind toward the study's specific objectives. We adopted a fairly liberal standard for designating clusters: at least some evidence of joint industrial and innovative activity in the same vicinity. Given the less-developed nature of much of the Appalachian region, we sought to avoid overlooking sub-regions with potential for expansion in various technology areas. Certainly, some identified clusters are much stronger than others. An understanding of differences in the relative depth of clusters in various areas can be derived from Table 19, which indicates the types of technology activity found in each sub-region.

More generally, the measurement of technology-related industrial activity and innovative output (by industries, universities, and other research performers) is hampered both by limited data and the complexity of the technology sector itself. The problem is compounded when the goal is to isolate localized, sub-state geographic concentrations of such activity over a broad and diverse 406-county area. Data and measurement limitations include, among other things, industrial classification schemes that fail to properly characterize the activities of individual businesses; the lack of consistent sub-state data for indicators such as value-added and productivity; inexact concordances between patent, disciplinary, and industrial technology areas; and the diversity of the technology sector itself, which mitigates against adhering to a narrow set of technology categories. Some smaller and more focused technology-related strengths in the region are undoubtedly missed when industries and programs are aggregated into a smaller set of technology areas.

At the same time, a methodology that is consistent across places and sectors is precisely what makes it possible to define technology clusters that are legitimate strengths in the U.S. economy from the perspective of industrial, academic, and federal/state program size and performance. The adoption of relatively narrow and self-contained definitions and the utilization of transparent complimentary analytical techniques (e.g., input-output, spatial statistics, and university rankings), while not without costs, is what permits the systematic evaluation of technology-related activity in and nearby the ARC region against a national benchmark.

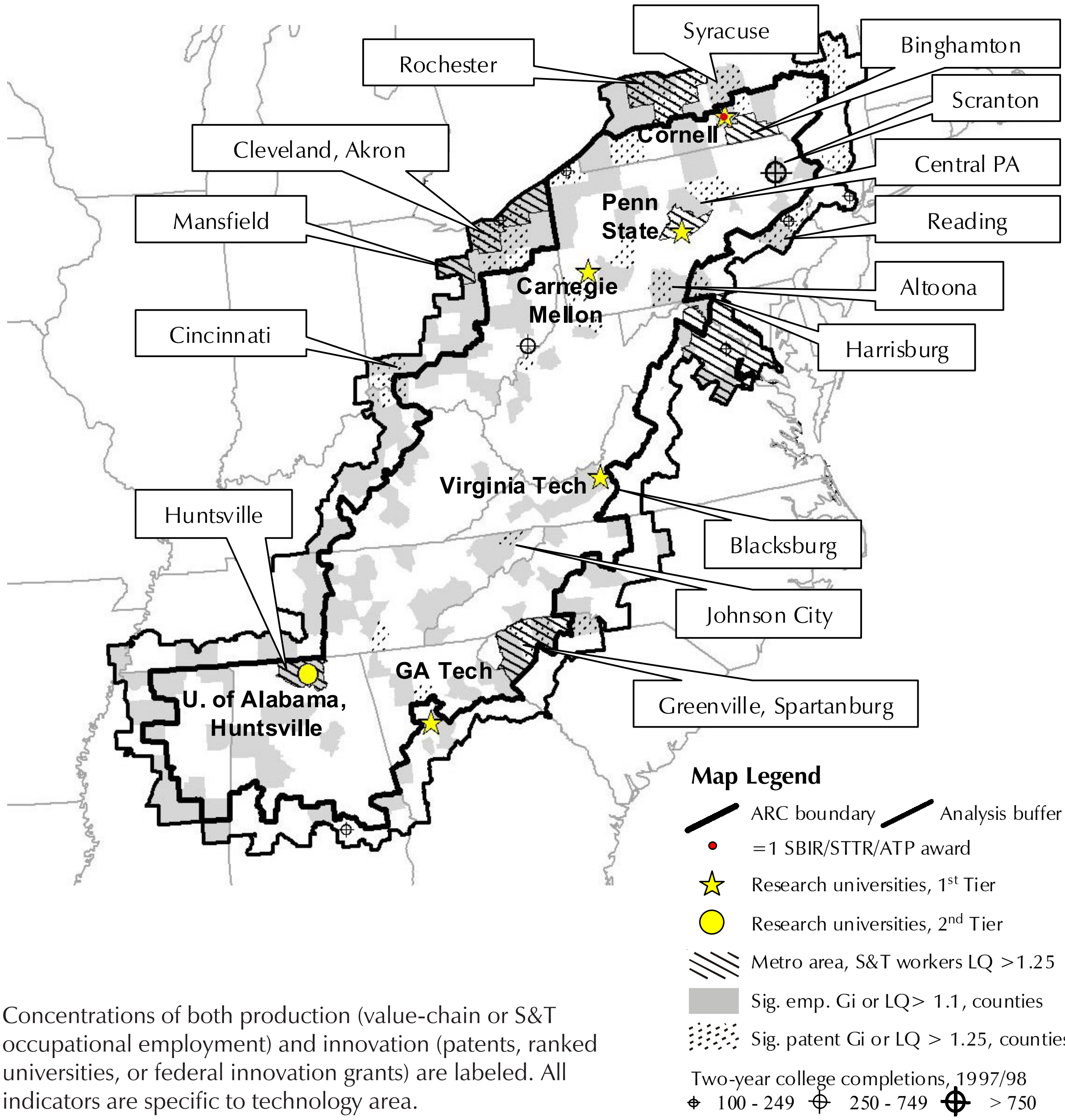
Figure 36
Technology clusters: Chemicals and plastics



Concentrations of both production (value-chain or S&T occupational employment) and innovation (patents, ranked universities, or federal innovation grants) are labeled. All indicators are specific to technology area.

Figure 37

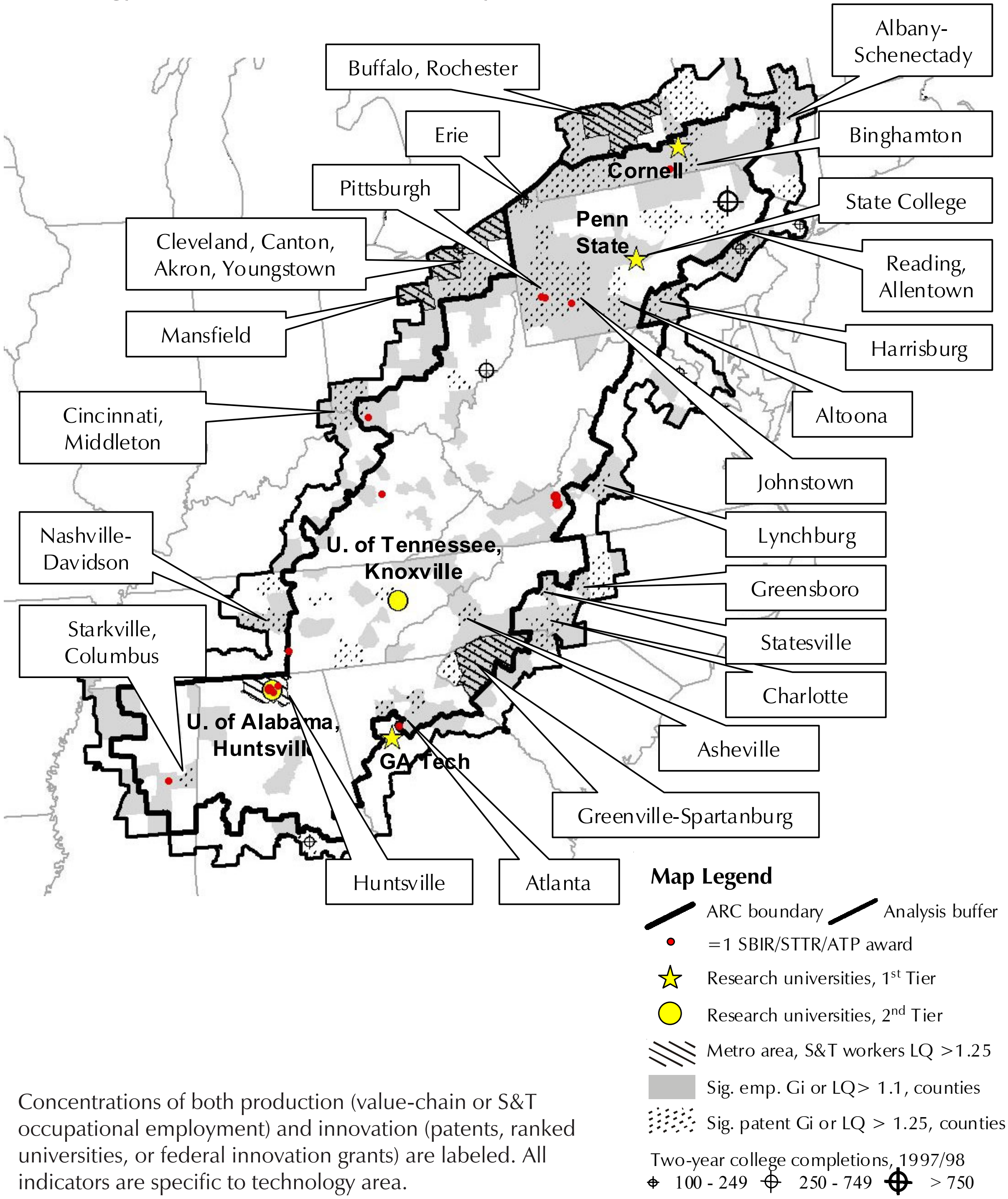
Technology clusters: Motor vehicles and related



Concentrations of both production (value-chain or S&T occupational employment) and innovation (patents, ranked universities, or federal innovation grants) are labeled. All indicators are specific to technology area.

Figure 38

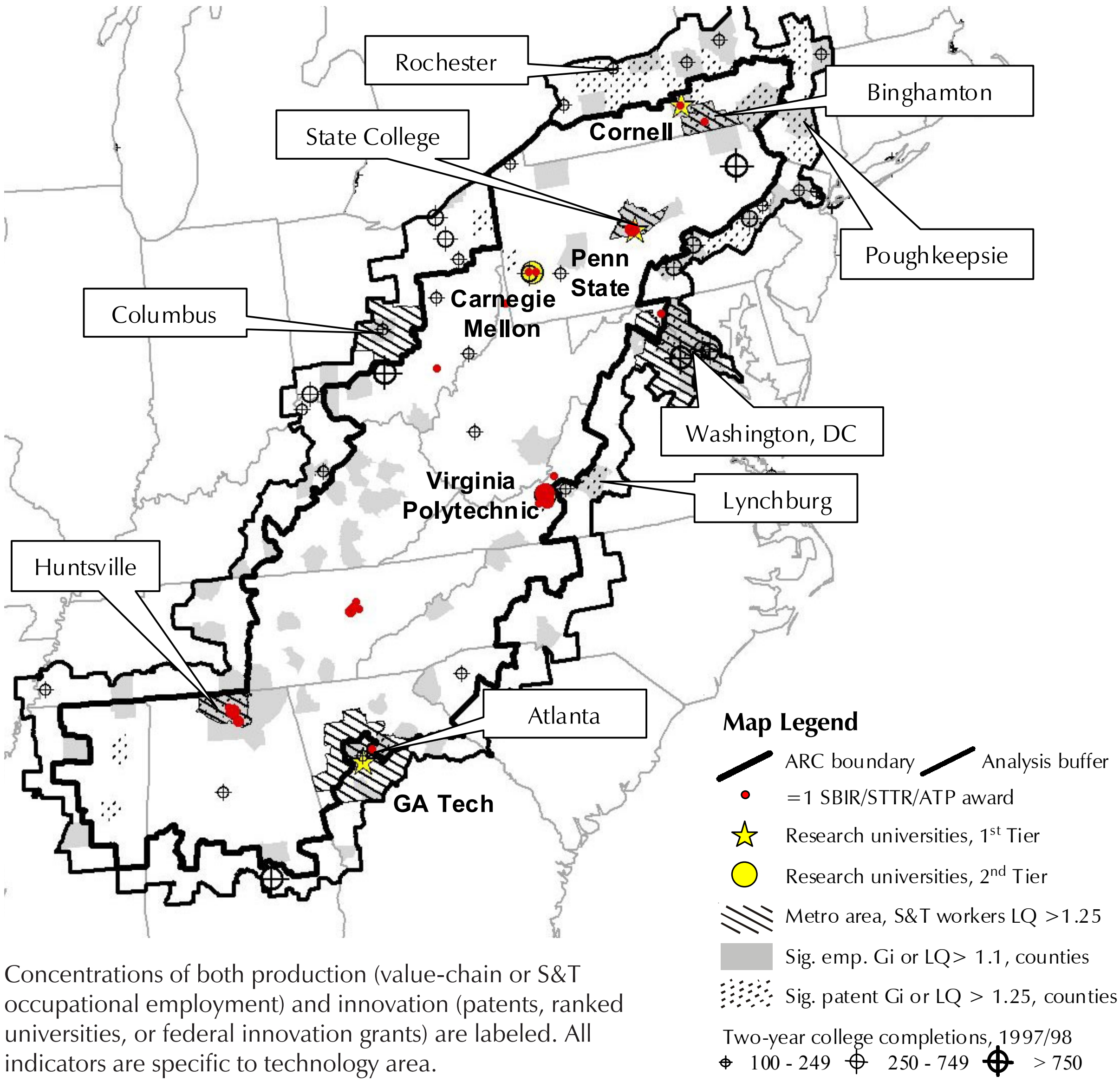
Technology clusters: Industrial machinery



Concentrations of both production (value-chain or S&T occupational employment) and innovation (patents, ranked universities, or federal innovation grants) are labeled. All indicators are specific to technology area.

Figure 39

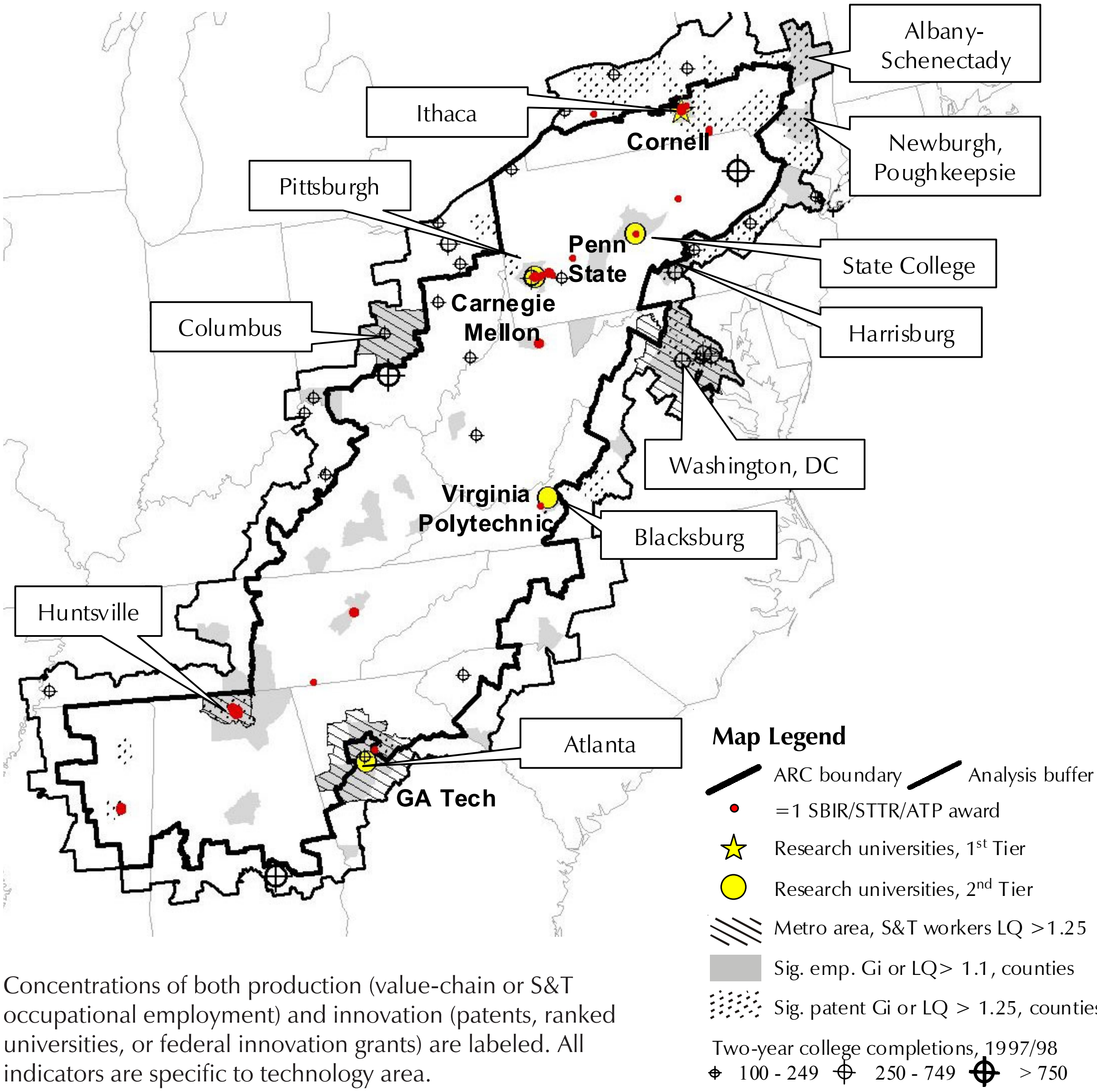
Technology clusters: Information technology and instruments



Concentrations of both production (value-chain or S&T occupational employment) and innovation (patents, ranked universities, or federal innovation grants) are labeled. All indicators are specific to technology area.

Figure 40

Technology clusters: Communications services and software



Concentrations of both production (value-chain or S&T occupational employment) and innovation (patents, ranked universities, or federal innovation grants) are labeled. All indicators are specific to technology area.

4.2 Findings

While there is no need to discuss every cluster in Table 19 individually, there are several general findings that emerge from the analysis. First, Appalachia's principal localized technology-related strengths at the present time are in three major areas: chemicals/plastics, industrial machinery, and motor vehicles and related industries.[41] Those three traditional "sectors" account for 58 of the 100 clusters identified. Only four to eleven localized clusters could be found for each of the remaining six technology areas. Moreover, in the remaining six technology areas, the Washington, DC, Huntsville, Pittsburgh, Atlanta, and Ithaca/Binghamton regions account for eighteen of the 42 clusters identified.

Second, the distribution of clusters throughout Appalachia is highly uneven. Nearly half (45 in total) of the region's technology clusters are located in the northern third of the region (New York, Pennsylvania, and northern Ohio). Only nineteen clusters were identified for central Appalachia (an area that includes southern Ohio, West Virginia, Virginia, and Kentucky), with Cincinnati and Washington, DC accounting for nine of those nineteen. In the southern third of the region, Atlanta, Greenville-Spartanburg, and Huntsville account for sixteen of 29 clusters identified. The geography of clustering in the region is a function of both the general historical distribution of industrial activity as well as the limited presence of leading universities in central and southern Appalachia. The distribution of federal grants (e.g., SBIR/STTR/ATP) also tends to favor the north, especially if grants in the Huntsville area (originating from organizations linked to large area federal labs and defense installations) are excluded.

Third, the uneven geography of the clusters in the region varies substantially by technology area. The chemicals/plastics and information technology/instruments clusters are relatively evenly distributed amongst the northern, central, and southern thirds of the region. Industrial machinery, on the other hand, is nearly exclusively a northern and southern strength. Indeed, there are two large-scale dominant concentrations of industrial machinery activity in the region: along the northern ARC border in the states of Ohio and New York and extending over much of Pennsylvania, and along the Interstate 85 corridor of North Carolina, South Carolina, and Georgia. Other clusters are most common in the north: communications services and software, aerospace, and pharmaceuticals and medical technologies.

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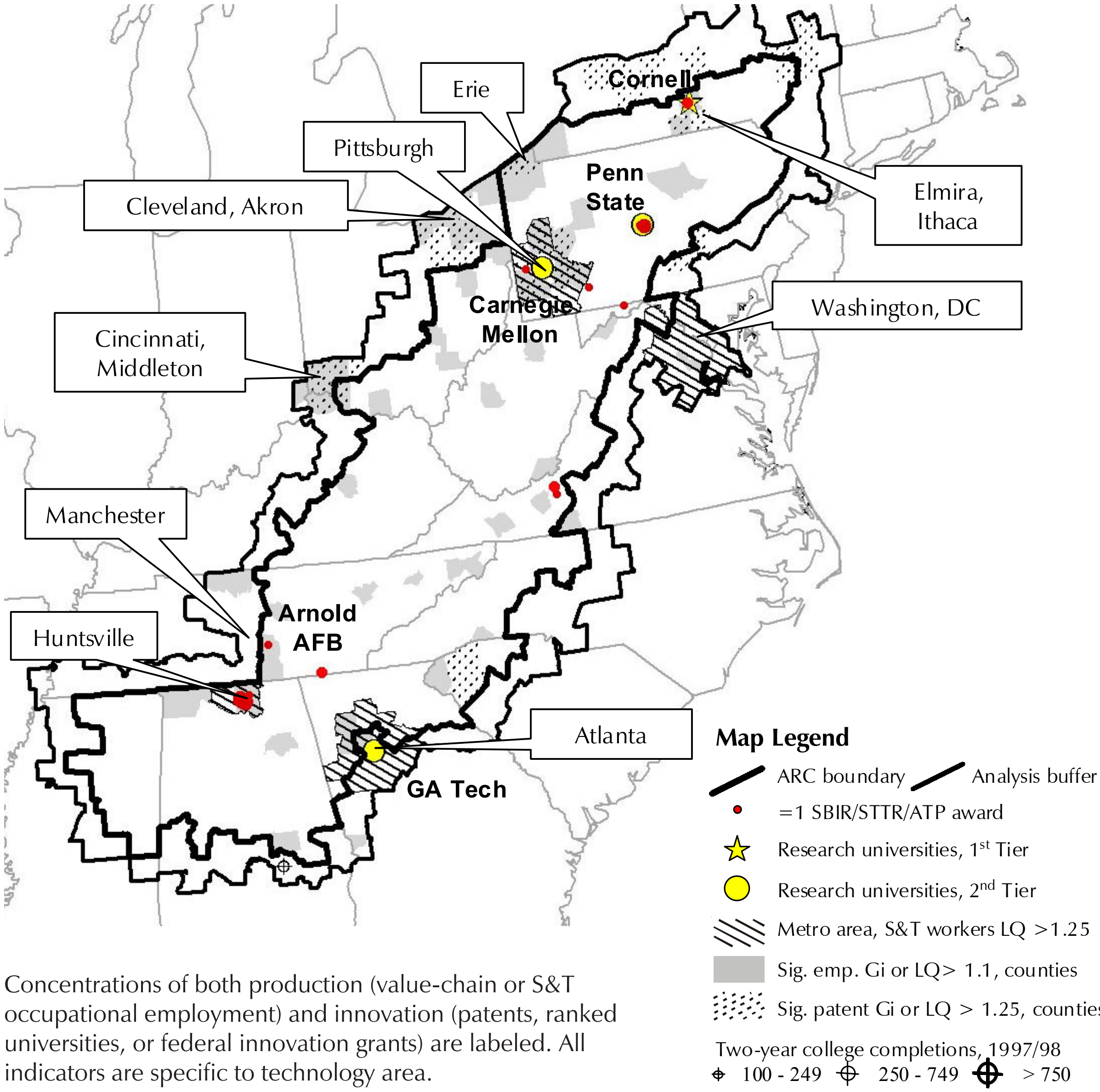
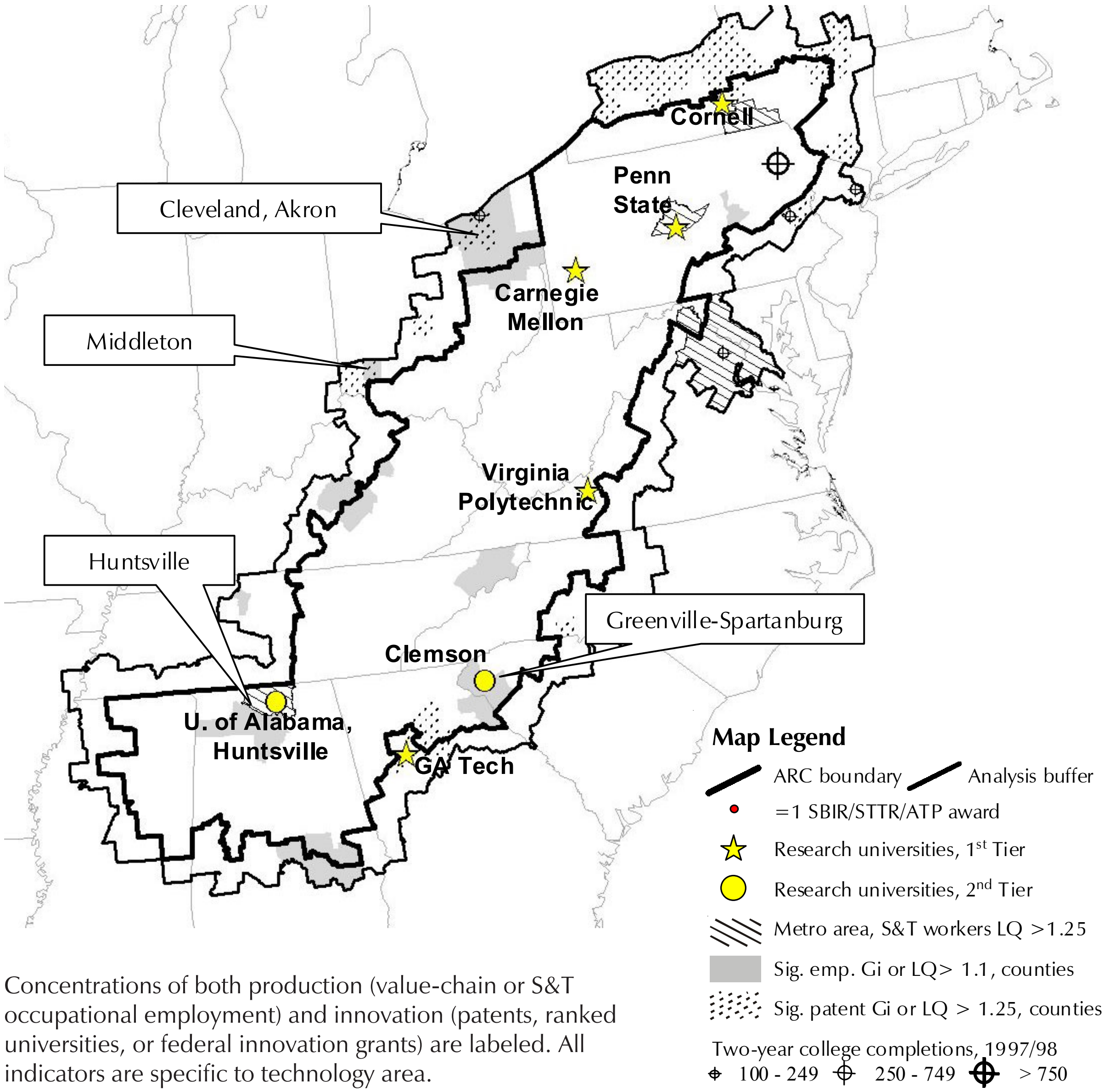
41. It is important to note that the specific geography of the clusters is inexact. Modifiable areal unit problems and limitations in individual measures limit our capacity to isolate the exact boundaries of concentrated activity. That is why we include multiple measures (location quotients, *G* statistics) and units of analyses (metropolitan areas, counties, and ZIP codes). We have focused on locations where results from the different indicators and units of analysis tend to overlap. It follows that our areal labels in Table 19 and in Figures 36–43 describe only the general vicinity of given clusters and should not be interpreted narrowly or exclusively (e.g., most of the clusters labeled as "Pittsburgh" extend across the greater Pittsburgh region).

Figure 41
Technology clusters: Aerospace



Concentrations of both production (value-chain or S&T occupational employment) and innovation (patents, ranked universities, or federal innovation grants) are labeled. All indicators are specific to technology area.

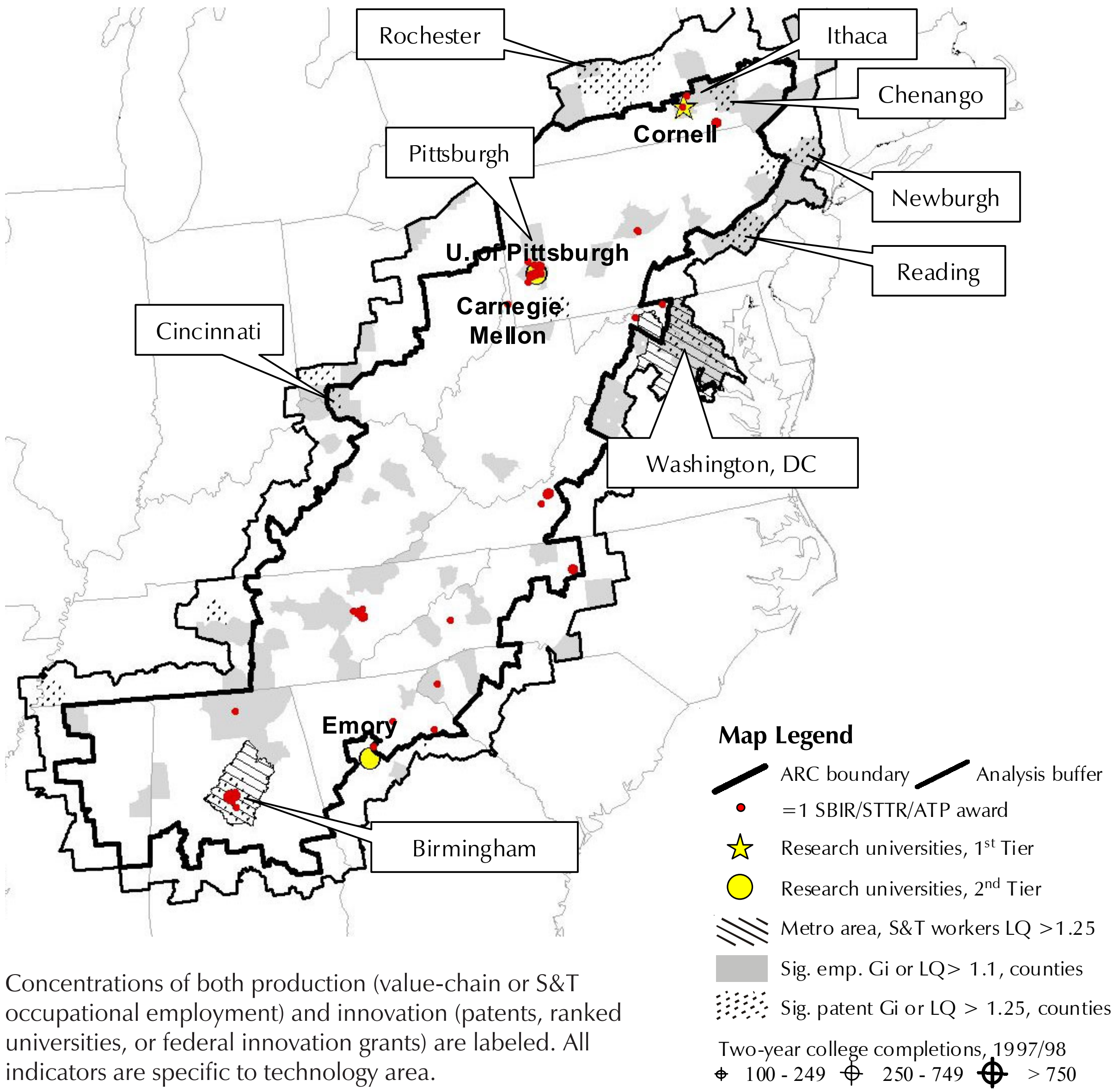
Figure 42
Technology clusters: Household Appliances



Concentrations of both production (value-chain or S&T occupational employment) and innovation (patents, ranked universities, or federal innovation grants) are labeled. All indicators are specific to technology area.

Figure 43

Technology clusters: Pharmaceuticals and medical technologies



Concentrations of both production (value-chain or S&T occupational employment) and innovation (patents, ranked universities, or federal innovation grants) are labeled. All indicators are specific to technology area.

Fourth, just over half of the technology clusters in the region are located on the periphery and are anchored in core metropolitan centers outside the region (such as Cincinnati, Atlanta, and Washington, DC). There are few predominantly rural clusters, as is expected given a methodology that essentially considers both relative and *absolute* size as barometers of a cluster's strength.[42] The following summarizes findings for each technology area, with an emphasis on identifying the clusters of greatest competitive strength.

- *Chemicals and plastics:* Particularly strong clusters are in the areas of Binghamton and Ithaca, Newburgh, Reading/Allentown, Cleveland and Akron, Charleston, Greenville-Spartanburg, and Auburn, AL. State College, anchored by R&D activity at Penn State, is another significant area of chemicals and related activity.
- *Motor vehicles and related:* Strongest clusters are in Rochester, Binghamton, Cleveland and Akron, and Greenville-Spartanburg. Most industrial employment in motor vehicles and related supplier industries is situated along the border of the region and tracks Interstates 71 and 75 through Ohio, Kentucky, and Tennessee. In this cluster, the location of industry activity is coincident with innovative activity only infrequently.
- *Industrial machinery:* Strongest clusters are in Buffalo and Rochester, northeastern Ohio, Mansfield, and Greenville-Spartanburg. Lynchburg and Cincinnati are the only two clusters identified in central Appalachia.
- *Information technology and instruments:* Strongest clusters are in Binghamton (birthplace of IBM), State College, Washington, Atlanta, and Huntsville. Community colleges provide substantial training in related fields, particularly in Washington, DC, eastern Pennsylvania, northern and central Ohio, and Pittsburgh. Overall, the region's knowledge infrastructure in information technology is considerably stronger than its industrial base.
- *Communications services and software:* Strongest clusters are in Washington, DC, Atlanta, and Huntsville. As in the case of information technology, the industrial component of the cluster is much weaker than the knowledge and innovation component.
- *Aerospace:* Strongest clusters are in Pittsburgh, Atlanta, and Huntsville. Washington, DC boasts a heavy complement of scientists and engineers in related occupations but a comparatively modest industry concentration, perhaps reflecting the dominance of federal government activity (e.g., defense) in the area.
- *Household appliances:* Very little evidence of clustering in Appalachia; leading concentrations in Cleveland and Akron, Huntsville, and Greenville-Spartanburg.

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42. It is important to emphasize as well that the current study does not consider the degree to which peripheral Appalachian communities actually do enjoy spillovers from metropolitan clusters located adjacent to the ARC region. However, the analysis in this study — especially that in Chapter 2 — can identify candidates for additional research focused on that question.

- *Pharmaceuticals and medical technologies:* Dominant clusters are near Ithaca and Chenango County, NY, Pittsburgh, Washington, DC, and Birmingham. There is a substantial concentration of related industry employment in Huntsville but a weak supporting knowledge infrastructure.

4.3 Policy Implications and Guides

This study has identified 100 sub-regional concentrations of technology-related economic activity and innovation within and immediately adjacent to the 406-county ARC region. Many of the clusters are in traditional manufacturing (chemicals, motor vehicles, and industrial machinery). Overall, we found that Appalachia's industrial base is oriented toward high tech industries of moderate technology-intensity. The most technology-intensive industries — including information technology, software, aerospace, and scientific instruments — are under-represented in the region relative to the national average industry mix. Likewise, the joint spatial clustering of business and innovation/R&D in some very high-tech sectors such as information technology, software, and aerospace is 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.

Furthermore, a great many of the region's clusters are located on its periphery. The ARC region's current high-tech prospects are therefore heavily dependent on spillover (or "spread") effects from neighboring cities and metropolitan areas. Unfortunately, those spillover effects are neither certain nor necessarily positive. High-tech concentrations in border metro areas such as Washington, DC, Cincinnati, Columbus, and Atlanta may draw away talented graduates from Appalachia's colleges and universities, leaving the region without the human capital base necessary to fuel technology-related growth. Given the power of first mover advantages and subsequent agglomeration economies common to technology-based industries, the prospect of negative geographic spillover (or "backwash") effects from larger neighboring jurisdictions is a very real one. Backwash effects result when growth in urban centers drains human and financial resources from peripheral regions.

What should regional policymakers do with the extensive information on Appalachia's technology clusters that this report provides? How can technology clusters in Appalachia be nurtured and expanded? The concept of a technology cluster — a joint concentration of industrial production and innovative activity — suggests three principal avenues of intervention: targeting cluster sectors for growth and expansion by entrepreneurship and recruitment programs (addressing the business component of clusters); improving research and education capabilities in scientific and technical fields (the knowledge infrastructure component of clusters); and leveraging productivity-enhancing agglomeration economies and knowledge spillovers shared by cluster firms and supporting institutions (usually by maximizing opportunities for collaboration, learning, networking, joint problem-solving, and the like).

4.3.1 Industrial Targeting

One of the most common and direct applications of the cluster concept is the application of conventional economic development strategies (especially recruitment and entrepreneurship programs) to underdeveloped elements of industry clusters (Anderson 1994). Cities and states in the ARC region can subject each individual technology cluster identified in this report to further detailed analysis to determine that cluster's underlying industry mix, its recent pattern of growth and decline by sector, and the growth prospects of related industries that are under-represented or entirely absent. Promising sectors can then be evaluated for feasibility as development targets based on their typical location requirements (in terms of infrastructure, workforce, market, input supply, amenities, and environmental impact). The idea is to implement a business development strategy that plays to — and expands — the region's demonstrated strengths in production and R&D, thereby increasing the complement of higher wage, technology-oriented activity.

4.3.2 Knowledge Infrastructure

Another area of public sector intervention is the development of a high quality knowledge infrastructure. What characterizes technology clusters is not only high-tech businesses, but also the presence of important supporting institutions such as research universities, teaching universities and community colleges, and non-profit and private-sector contract research houses and laboratories. DeVol (2000, p. 34) argues that "research centers and institutions are indisputably the most important factor in incubating high-tech industries." The concept of clusters has piqued the interest of state, regional, and federal development agencies because it implies clear avenues for policy in areas in which the public sector has traditionally, and often very successfully, engaged. The finest research and teaching universities in the country — whether private or public — owe a good part of their success to federal and/or state funding, the federal government has long been a major supporter of basic research, and many states are becoming direct players in the technology arena by establishing centers for biotechnology, information technology, electronics, and other areas of applied research (Jankowski 1999, Schacht 2002). Given the limited success of efforts to recruit relocating businesses (high-tech or otherwise), governments are increasingly attempting to aid the growth of technology clusters by doing what they have traditionally done well: support basic research, education, and training.

That is not to argue that government support for research and technology-oriented education and training in a specific region is guaranteed to generate or expand a technology cluster with dynamic high-tech, high wage companies at its core. Exactly how to implement such a strategy is still unclear and much research remains to be done both on the link between research and education and job creation and on the rationale for government support for business R&D (e.g., see Tassey 1999; Wallsten 2000b; Wallsten 2000a). Most states are currently in various stages of policy experimentation, with some focusing on university technology transfer, others establishing "centers of excellence" in specific areas of research, and still others funneling resources into applied science and engineering training at the community college level. But the attractiveness of such strategies, even in the face of uncertainty with regard to efficacy, is explained by their potential to yield a broad range of benefits with different degrees of certainty. The establishment of a leading research focus area (or "center of excellence") within a university or non-profit organization, for example, is a benefit aside from its potential to attract companies or spin off new business ventures. Likewise, education and training yield civic, social, and quality of life benefits apart from the immediate connection between quality human capital and business investment. Thus the pursuit of technology clusters offers the prospect of a more diverse portfolio of social outcomes and benefits than conventional business recruitment and marketing strategies.[43]

Cities and states in the ARC region should use the findings in this report to identify investments in knowledge infrastructure that will do two things: first, ensure that there is a sufficiently skilled labor force for technology-related industrial growth; and, second, maximize complementarities between innovation and industrial competencies. The workforce skills question can be addressed by determining whether university and community college programs are meeting the needs of technology sectors in identified clusters within specific Appalachian sub-regions. Given the narrow requirements of many technology businesses, a case-by-case analysis is necessary as a follow-on to our general assessment. Synergies between the industrial and innovation components of the clusters can be fostered by strengthening university or non-profit R&D strengths in disciplines that dovetail with growing technology sectors. Again, the first step is to take the technology clusters identified in this document and break them down further into much narrower areas of industrial and R&D strength.

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43. The logic presumes that the given investment, in this case an engineering school, is pursued based on criteria apart from — or at least in conjunction with — business creation objectives. There is a very real risk that government will over-supply research and education in its effort to create technology jobs. A partial example of this pitfall is documented by Luger and Goldstein (1991) in an analysis of the university research park craze of the 1980s.

4.3.3 Leveraging Spillovers and Agglomeration Economies

A third area of development policy intervention implied by the cluster concept is the promotion or leveraging of productivity-enhancing spillovers and economies shared by the technology businesses at the core of each cluster. In point of fact, aside from promoting the growth of the cluster to encourage external economies of scale, appropriate policy options are limited to establishing venues or mechanisms for business collaboration and information exchange. Cities or states can encourage the creation of a trade association or other private sector organization charged with defending and promoting the shared interests of firms in a given cluster. Typically, such organizations also help market the region as a location for related businesses, hold networking events and conferences, and provide a natural standing venue for businesses to bring infrastructure, workforce development, regulation, and taxation concerns to the attention of public agencies, universities, and community colleges. Absolutely essential to the success and efficacy of such organizations is a clear articulation of the benefits firms can gain — even if they are direct competitors — by collaboration on at least some issues (e.g., regulatory reform, public infrastructure, etc; see Dalsgaard 2001). A common thread in the research literature to date is that firms rarely know they are part of clusters, let alone that they benefit from efforts to further develop the same.

4.4 Further Research

This study provides only the broadest picture of the regional distribution and orientation of Appalachia's technology-related assets and activities. A number of important issues with respect to the proper formulation of economic development policy in Appalachia remain unaddressed. Possible avenues for further research that builds on and expands the findings in this report include:

- The question of whether Appalachian sub-regions with a strong joint complement of industrial and innovative activity are growing faster — in income, employment, output, and/or productivity terms — than those without a strong knowledge infrastructure component. Some studies (e.g., O'Malley and Van Egeraat 2000) have found little evidence of a strong positive relationship between clustering and manufacturing growth, implying that public policies aiming to develop clusters will not yield significant growth impacts.
- The net spillovers impact of border technology clusters that are anchored outside the ARC region. Information on the migration trends of graduates from ARC universities, the location patterns of spin-offs from technology businesses and universities in the region, and cross-border linkages among firms in border clusters, while difficult to assemble, would provide a critical understanding of the likely influence of border cluster development on the economic prospects of Appalachia itself.
- The functional and organizational differences among otherwise similar technology clusters in Appalachia and the implications of those differences for the net

economic impact of technology clusters. Some clusters may be dominated by multi-locational firms headquartered outside the region while others may be indigenously based. Similarly, some clusters — the automotive cluster emerging in Greenville-Spartanburg — may be dominated by foreign-owned companies. Locally-based cluster companies may be more likely to generate spin-offs within the region, as well as link more closely with the research efforts of Appalachian universities and labs, therefore generating more significant economic impacts in the long-run.