Regional Technology Assets and Opportunities:

The Geographic Clustering of High-Tech Industry, Science and Innovation in Appalachia

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EXECUTIVE SUMMARY

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High-tech activities cluster and clustering spurs competitiveness. That is the message of a rapidly growing body of research showing that the geographic co-location of businesses, universities, colleges, and labs often yields powerful clusters of technology-related activity that continue to expand through initial market leadership and economies of scale. Well-known examples are information technology and biotechnology California's Silicon Valley and Boston's Route 128, software and aircraft in Seattle, and electronics and pharmaceuticals in North Carolina's Research Triangle. Such clusters have contributed to substantial increases in their regions' prosperity while also supplying the innovations that drive national economic growth.

This study constitutes a systematic location analysis of the technology assets of Appalachia. Specifically, the report identifies and documents sub-regional concentrations of technology-related employment, R&D, and applied innovation within and immediately adjacent to the 406-county service area of the Appalachian Regional Commission. By assembling and analyzing an extensive set of data at high levels of functional and spatial detail, the study reveals localized technology strengths that might be nurtured through focused economic development policy.

The study found 100 technology clusters — joint spatial concentrations of high-tech employment and innovative activity — within and adjacent to the ARC region. The clusters vary significantly in size, depth, and overall competitive strength. They span eight general technology areas: chemicals and plastics; motor vehicles and related; industrial machinery; information technology and instruments; aerospace; communications services and software; and pharmaceuticals and medical technologies. Chemicals and plastics, industrial machinery, and motor vehicles and related industries account for a majority of the technology clusters. Some of the detailed findings in the report include:

- Overall, Appalachia's technology sector is comparatively small but expanding. There were roughly 1.07 million workers employed in the region's high-tech industries in 1998, up from 959,000 in 1989, an increase of 11.2 percent. The rate of net technology employment growth between 1989 and 1998 was about two-thirds of the overall private sector growth rate. Most of the high tech gains occurred in sectors classified as "moderately technology-intensive," such as chemicals, electronic components, transportation equipment, instruments, and hospitals and health-related labs.
- In terms of a diversity of high-tech industry employment, there are five leading metropolitan areas in Appalachia: Binghamton, Greenville-Spartanburg, Huntsville, Johnson City, and Pittsburgh. We found evidence of high-tech concentrations in four or more high-tech sectors in at least parts of each of those cities (six and seven sectors in the cases of Greenville-Spartanburg and Huntsville, respectively). A second group of cities that are also home to multiple sectoral concentrations include Asheville, Decatur, Erie, Knoxville, and State College.
- Spatial employment concentrations in industrial machinery, chemicals/plastics, and motor vehicles tend to be larger in geographic extent (comprised of larger multi-county areas) than the other technology industries. That is, their presence in (or sometimes extension into) rural counties is more extensive than sectors such as information technology, communication services, and software.
- Within the ARC region proper, there is clearly an orientation of high-tech activity to the northern and southern thirds of the region, with activity in the central region very sparse in several key technology sectors. Chemicals and plastics industries exhibit the strongest presence in the central third of the ARC area, whether measured by value chain employment or occupational employment.
- Appalachian metro areas have a significantly lower complement of scientists, engineers, and technicians than the U.S. as a whole. Scientists and engineers are somewhat better represented in the MSAs that line the region's borders. Washington, DC accounts for a significant share of the total scientists and engineers employed in the 62 metro areas included in the study. Excluding the Washington, DC MSA finds the southern third of the extended region the most "science and engineering-intensive" based on occupational employment indicators.
- Based on national ratings of faculty quality, there are six major nodes of highest competitive research strength in the universities in Appalachia (either within or adjacent to the ARC region): Cornell (Ithaca, NY), Carnegie-Mellon (Pittsburgh, PA), Georgia Tech and Emory University (Atlanta, GA), Penn State (State College, PA), and Virginia Tech (Blacksburg, VA).
- According to faculty quality rankings, the greatest competitive strengths among Appalachian research universities as a group are oriented toward the engineering and physical sciences. According to national R&D funding rankings, some Appalachian universities are also very strong in the life sciences.

- A number of Appalachian universities boast research programs that are rising steadily in the national rankings (based on R&D funding and graduate student enrollments). The majority of such "emergent programs" are at Carnegie-Mellon, Georgia Tech, Ohio State, Penn State, the University of Kentucky, Virginia Tech, West Virginia University, and Mississippi State.
- Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), and Advanced Technology Program (ATP) award winners are concentrated in a relatively small number of places, namely Huntsville, Blacksburg, Pittsburgh, State College, and Ithaca, with smaller concentrations in Birmingham and Knoxville/Oak Ridge. The nature of the SBIR/STTR/ATP programs favors locations near universities and government labs.
- Industrial machinery is easily the most common technology focus among the some 220 SBIR/STTR/ATP awards in fiscal year 2000. That may reflect the dominance of the region's traditional industry sectors (textiles, apparel, furniture, and metals).
- There are a great many state-funded technology assistance, transfer, and modernization programs and agencies in the ARC region. Comparatively few, however, are focused on the two technology areas that are projected to drive significant growth in the next decade: information technology and biotechnology.
- Surprisingly, given the region's industry mix, Appalachian four-year universities and colleges grant proportionately fewer degrees in industrial engineering and related sciences than universities nationwide. Indeed, based on degree completions in 1997/98, Appalachian universities and colleges grant proportionately more degrees in basic medical science, environmental engineering and controls, mathematics, materials engineering and science, and biochemistry and biomedical engineering than national averages would predict.
- The share of annual degrees awarded in the computer and communications sciences by two-year colleges and institutes in Appalachia is substantially below the national average. That may reflect the comparatively limited job opportunities in IT-related industries in the region (a problem of labor demand) or an inadequate training network for an emerging industry (a problem of labor supply).
- Two- and four-year higher education institutions with an emphasis in technology are comparatively few in central Appalachia (Tennessee, Kentucky, West Virginia).
- The spatial distribution of the 100 technology clusters in Appalachia is highly uneven. Nearly half (45 in total) 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 uneven geography of the clusters in the region varies substantially by technology sector. The chemicals/plastics and information technology/instruments clus-

ters 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.

- 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). That means that the ARC region's current high-tech prospects are heavily dependent on spillover effects from neighboring cities and metropolitan areas. Unfortunately, those spillovers are neither certain nor necessarily positive.

The analysis and findings in this report have three major implications for state and local officials concerned with economic development in Appalachia. First, the technology clusters are potential targets for focused entrepreneurship and recruitment strategies. Each sub-regional technology cluster highlighted in this report can be subjected to further detailed analysis to identify linked end-market or supplier sectors that represent attractive growth prospects, or related industries that offer higher wages. Those prospects can then become the focus of comprehensive development strategies designed to nurture their growth.

Second, the report findings can be used to guide state investments in "centers of excellence" in the research universities, expanded specialized education and training programs in the region's teaching universities and community colleges, and in technology transfer and industrial extension programs. Some of the 100 technology clusters are characterized by a very strong base of science, innovation, and training. However, most are not, especially within the ARC region proper. While innovation and R&D strengths are in evidence in the case of all technology clusters, the clusters vary greatly in the depth and diversity of that strength. Moreover, some clusters are better served than others by the region's university and community college education and training system.

Third, a common step in many states' efforts to develop and expand technology clusters is the establishment of an industry association or other private sector entity charged with documenting and championing specific clusters' interests in the policy arena. Such organizations also often provide a venue for collaboration and joint problem solving among cluster firms (networking), thereby increasing opportunities for productivity-enhancing spillovers that are a critical part of firms' competitiveness. States and regions should view the clusters identified in this report as potential candidates for such "cluster organizing" and networking efforts.

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1 Introduction

Over the last 40 years, economic development progress has been substantial in many parts of Appalachia, the 406-county region that is the focus of the Appalachian Regional Commission (ARC). A recent study shows that the number of ARC counties identified as distressed declined from 214 to 106 between 1960 and 1990 (Wood and Bischak 1999).[1] That study attributes those gains to the growth of the manufacturing sector in predominantly southern rural counties, while also noting that they have come partly at the expense of traditional northern manufacturing centers. The study also noted the significance of positive spillovers from high growth metropolitan areas that border the Appalachian region, particularly in the South (with Atlanta as the premier example).

At the same time, Wood and Bischak report that about one-quarter of ARC counties that were distressed four decades ago remain distressed today. Furthermore, the prospects for the continued economic progress of Appalachia are uncertain, even in many of its currently non-distressed sub-regions. Much of Appalachia remains heavily dependent on unstable and cost-sensitive manufacturing, agriculture, and minerals extraction activity. Just as inexpensive labor and a more permissive regulatory environment initially brought manufacturing to southern Appalachia, foreign locations are now using similar advantages to lure those jobs away. As U.S.-based businesses substitute capital for labor to minimize costs, they are displacing workers, spurring out-migration from smaller communities with few alternative job opportunities, and increasing demands on workforce education and retraining programs.[2]

1. See also Feser and Sweeney (2002) who utilize an alternative methodology to compare 25–30 year trends in economic distress for all commuter zones in the contiguous U.S. Using distress thresholds based on long run trends, they identify eight Appalachian commuter zones as unemployment distressed in 1999 (the share of Appalachian population in those zones was 1.2 percent). Forty-two zones, accounting for 12.9 percent of Appalachian residents, were found to be income-distressed in the late 1990s.
2. Labor-saving technologies also continue to increase productivity in agriculture while reducing farm employment.

1.1 The High Technology Antidote

A growing number of state and local policymakers believe that a strong base of science and technology is a necessary foundation for sustained prosperity.[3] The view rests on three major arguments. First is the notion that with increasingly open international markets, businesses based in the U.S. must seek competitive advantage in America's knowledge infrastructure, including its world-leading private and public R&D institutions, educated workforce, tradition of risk-taking and entrepreneurship, advanced physical infrastructure, and stable and transparent social and political institutions. Concerns over issues like the "digital divide," equal access to education, and worsening income inequality are heightened by fears that two sectors are coming to dominate long-term domestic employment growth prospects: high skilled technology-intensive activities that are dependent on advanced knowledge infrastructure and low-skilled basic consumer services that serve immediate local market needs. While the prospect of a "two-tiered economy" remains hypothetical rather than an empirically-verified fact, it has gained significant traction in policy debates at the state and local levels.

The second argument for a close link between technology and regional economic performance is based on studies of recent sectoral growth trends. For example, in an analysis predating the 2001 recession, Hecker (1999) projected that high-tech and related employment would grow twice as fast as employment in the rest of the economy over the 1996 to 2006 period. Another study finds that the global market for the products of four research-intensive industries — aerospace, computers and office machinery, electronics and communications, and pharmaceuticals — expanded over twice as fast as the markets for other manufactured goods over the 1980 to 1995 period (Rausch 1998). Certainly, not all industries cited by various studies as "technology-intensive" are posting employment or output gains. Indeed, some tech sectors faced significant declines during the 1990s. But even with uncertainty over the recent recession as well as how best to define the technology sector (e.g., see Pollak 1999 and Wirtz 2001), most studies show that gains in technology-related employment have been strong relative to other industries over the last decade. By most measures, technology sectors also pay considerably higher wages than more traditional industries, particularly in the manufacturing sector.

The third argument for technology as a key to regional economic development is that technology-related activity must necessarily cluster in specific regions because knowledge spillovers are *localized* (Glaeser 2000). Knowledge spillovers — the primary engine in the most recent theories of long-run

3. A recent statement of the importance of high technology for cities and regions that has been highly influential in policy circles is Atkinson and Court (1998). The support for technology policy often is based as much on a hunch than a research consensus. As one government report claims OTP (2000, p. 1-1), "the relationship between measures of economic prosperity and science and technology capacity is intuitive. Such relationships have lead to public policies to support economic development through science and technology investments."

economic growth — are the ability of economic agents to utilize a new technology or innovation without fully compensating its original source or owner (Grossman and Helpman 1991). Innovations initially occur in companies, universities, and laboratories located in specific places. The subsequent spread (or diffusion) of such innovations, as well as the spillovers they generate, may occur more readily among economic actors located in close proximity, either because the innovation is tacit in nature or because its successful utilization requires an element of hands-on learning-by-doing. Increasing returns to innovation, coupled with a localized diffusion effect, imply that technology-oriented activity and R&D are likely to concentrate geographically. Technology businesses locate near other high tech companies and R&D performers in order to share in the spillovers, further enhancing the attractiveness of the growing cluster for still more high tech enterprises. The cluster expands through a process of cumulative advance.[4]

Indeed, a growing body of empirical work indicates that a combination of geographically co-located private sector producers of R&D, related manufacturing and services industries, linked or related suppliers and producer services providers, leading research universities and teaching institutions, and government sponsored labs and technology programs can combine to create powerful clusters of technology-related activity that continue to expand through initial market leadership (often called "first-mover effects") and economies of scale (Porter 1990; Saxenian 1994; Porter 1998; Porter 2000; den Hertog, Bergman *et al.* 2001). Well-known examples are California's Silicon Valley and Boston's Route 128 (in information technology and biotechnology), greater Seattle (in software and aircraft), and North Carolina's Research Triangle Park (in electronics, computers, and pharmaceuticals/biotechnology).

4. It has long been understood that technological change is the leading contributor to long-run economic growth (Nelson 1996). But prior to the mid-1980s, growth economists essentially viewed technological change as something that dropped from the sky. That is, the neoclassical perspective as laid out initially by Solow (1956, 1957) viewed technology as *exogenous*: not a direct function of the everyday process of capital accumulation, but rather a separate unexplained dynamic that confers productivity gains to capital, thereby ensuring sustained investment and perpetual growth in the long-run. Sustained long-run growth is, of course, what is observed in industrialized countries. The attractiveness of the exogenous technological change assumption, despite its limited face validity, must be understood in the context of growth economists' desire to retain the assumption of competitive markets (see Krugman 1995 for a good discussion).

The new growth theory, following advances by Romer (1986, 1990) and Lucas (1988), brings technological change into the model (i.e., makes it *endogenous*) through the mechanism of increasing returns. As a form of knowledge, a new technology is both nonrivalrous (the use of the technology by one economic agent does not preclude its use by another) and nonexcludable (the prevention of the unauthorized use of the technology by other economic agents is difficult). Those public good features are what give rise to knowledge spillovers. Resources are utilized to create new knowledge, some part of which "spills over to the research community, and thereby facilitates the creation of still more knowledge" (Grossman and Helpman 1991, p. 17). Because spillovers imply that the process of invention exhibits increasing returns to scale, returns to new productivity-enhancing technologies and ideas are always sufficient to maintain the incentive to invest in still more innovation. The result is long-run perpetual growth. Cortright (2001) provides an introductory treatment of new growth theory.

Such clusters have contributed to substantial increases in their regions' prosperity while also supplying the innovations that drive long-run national economic growth.

1.2 Appalachia's Technology Base

Appalachia's technology sector is comparatively small but expanding. By our count, there were roughly 1.07 million workers employed in the region's high-tech industries in 1998, up from 959,000 in 1989, an increase of 11.2 percent (see Table 1 and Figure 1).[5] The rate of net technology employment growth between 1989 and 1998 was about two-thirds of the overall private sector growth rate. Most of the high tech gains occurred in sectors classified as "moderately technology-intensive," such as chemicals, electronic components, transportation equipment, instruments, and hospitals and health-related labs. The typical worker in Appalachia's technology sector earned $35,204 in 1998, 135 percent of the region's average private sector wage (of $26,041). With 12.6 percent of its private sector workforce employed in high tech industries in 1998, compared to a 14.2 percent nationwide, Appalachia is less technology-intensive than the U.S. as a whole.

Table 1

Technology industry employment and wages, 1989, 1998

United States*	Employment				Payroll		
Sectors	1989 (000's)	1998 (000's)	% private sector '98	% Change '89-'98	1998 (Mil $)	% private sector '98	Average wage $
Very tech-intensive	4,105	4,687	4.5	14.2	268,592	8.1	57,311
Moderately tech-intensive	6,638	7,575	7.3	14.1	286,022	8.6	37,757
Somewhat tech-intensive	2,484	2,497	2.4	0.5	102,387	3.1	41,001
All tech sectors	13,226	14,759	14.2	11.6	657,001	19.8	44,515
Total private sector	96,029	104,258	100.0	8.6	3,310,187	100.0	31,750

Appalachia	Employment				Payroll		
Sectors	1989 (000's)	1998 (000's)	% private sector '98	% Change '89-'98	1998 (Mil $)	% private sector '98	Average wage $
Very tech-intensive	190	206	2.4	8.4	8,995	4.1	43,628
Moderately tech-intensive	525	614	7.3	17.0	19,761	9.0	32,164
Somewhat tech-intensive	243	246	2.9	0.9	8,777	4.0	35,738
All tech sectors	959	1,066	12.6	11.2	37,534	17.1	35,204
Total private sector	7,292	8,443	100.0	15.8	219,867	100.0	26,041

Source: U.S. Bureau of Labor Statistics, ES-202 files. *U.S. figures exclude Alaska, Hawaii, and Wyoming. Appalachia includes only the 406-county ARC region.

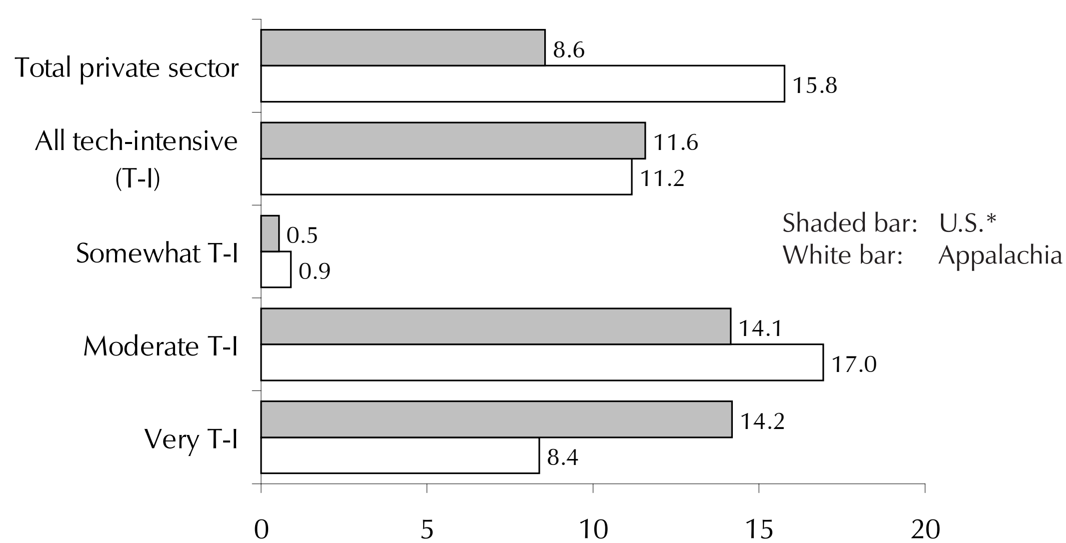
5. The data in Table 1 and Figures 1 and 2 are based on a classification of technology sectors developed by the North Carolina Employment Security Commission, which based its scheme on U.S. Bureau of Labor Statistics and National Science Foundation studies of the share of science and engineering workers by sector. The full classification is reported in Appendix Table 1. The source data are confidential U.S. BLS employment statistics (described in the Methods Appendix). Note that the U.S. figures exclude data for Alaska, Hawaii, and Wyoming, states that did not grant us permission to use their confidential employment data.

While U.S. technology employment growth only outpaced Appalachia's by a slight margin over the 1989 to 1998 period, many of the national gains occurred in industries classified as "very technology intensive," such as pharmaceuticals, computers, aerospace, software, and research and testing organizations. In 1998, those industries' paid average annual wages that were 181 percent of the U.S. private sector average. Overall in 1998, the national average "technology wage premium" — the ratio of wages in the technology sector to the private sector average wage — was six points higher than Appalachia's (at 141 percent), reflecting an Appalachian technology sector that is modestly skewed toward the less technology-intensive of the technology industries (see Figure 2).

Table 1 reports only private sector, non-educational employment in technology-related manufacturing and non-manufacturing industries.[6] Other components of Appalachia's science and technology base include its major research universities (eleven in total), network of teaching universities and community colleges (granting over 35,000 degrees in fifteen major science and engineering fields in 1997/98), and non-university laboratories (e.g., Redstone Arsenal in Alabama, Oak Ridge in Tennessee, and NASA in West Virginia). Also contributing to the region's science base are technology-intensive businesses, universities, colleges, and labs ringing its border.

Figure 1

Percent employment growth, technology-intensive industry, 1989-98



Source: U.S. Bureau of Labor Statistics. *Excludes WY, AK, & HI.

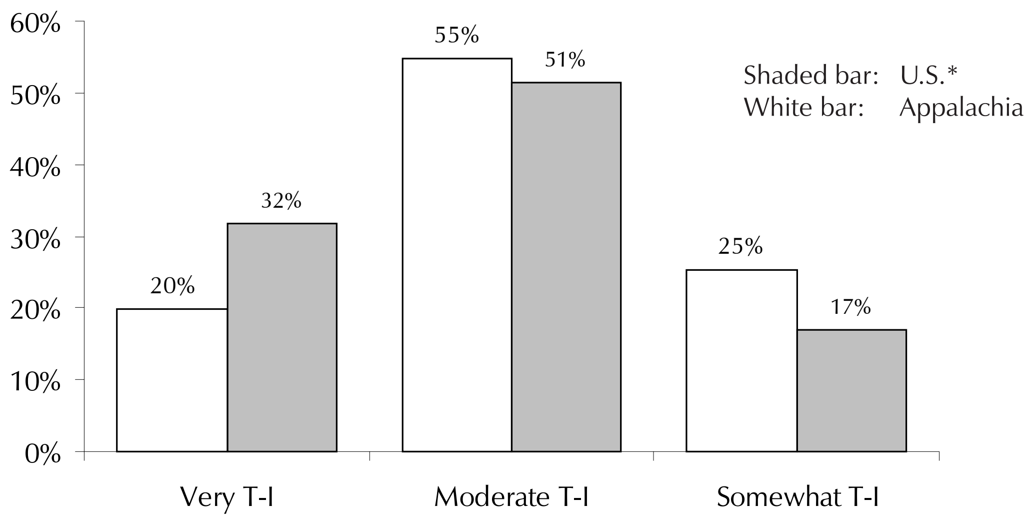
6. Employment in private universities is also not included.

1.3 Study Objectives

How important is technology to Appalachia? Behind the hype on high-tech are a series of often unexamined claims about the role of knowledge infrastructure in the economy. Solid evidence of a dramatic shift in U.S. comparative advantage toward knowledge-intensive production and services is surprisingly sparse, some regions have achieved considerable economic growth even with modest science and technology assets, and the proliferation of information technologies would seem to imply that the localization of innovation may be less critical for productivity than it once was. Even the view that the U.S. economy is becoming significantly more open, a common explanation for manufacturing job losses in the non-recessionary 1990s, has been subject to dispute (e.g., see Krugman 1995).

While such questions are extremely important, they are beyond the scope of this study. We take as a point of departure that the state and local governments of Appalachia are looking to nurture their promising technology assets. Doing that effectively requires knowledge of the location and characteristics of those assets. In that context, the principal objectives of this study are to systematically inventory the R&D, innovation, and technology specializations in the 406-county Appalachian region, and, most importantly, to expose and document any localized clusters of such activity. The report aims to provide a detailed analysis of the spatial distribution and concentration of Appalachia's science and technology strengths, as well as examine the strengths and concentrations of neighboring regions that may spillover into the Appalachian region. We also discuss the policy implications of the findings, particularly in light of the uncertain evidence of the exact relationship between knowledge infrastructure and regional economic growth.

Figure 2
Technology-intensive sector mix (T-I), 1998
Percent share of total technology employment by sector



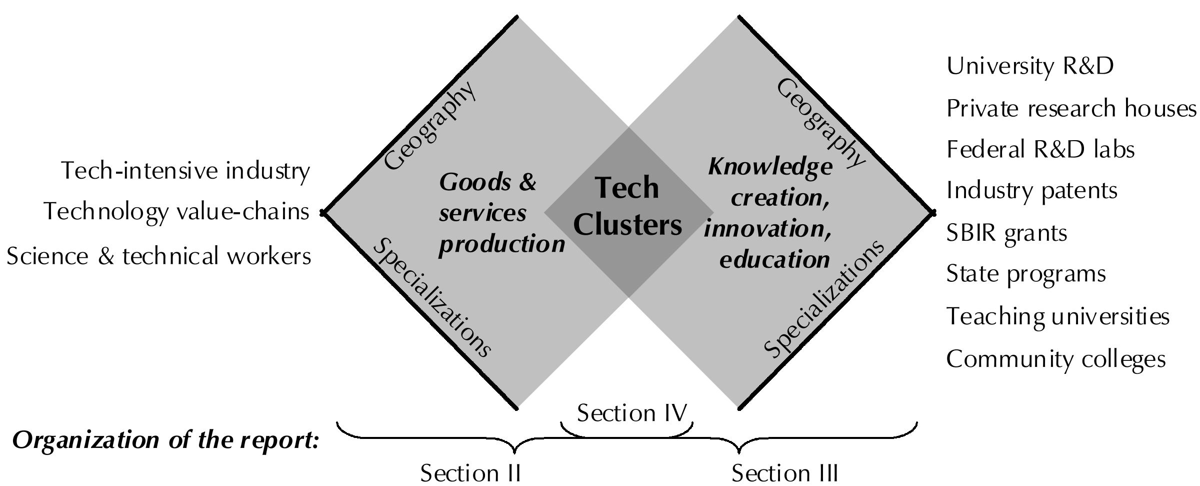
Source: U.S. Bureau of Labor Statistics. *Excludes WY, AK, & HI.

1.4 Conceptual Framework and Report Organization

Figure 3 summarizes the study conceptual framework. We examine technology-related assets within and near Appalachia from two perspectives: the industrial base (technology-related goods and services production and employment) and the knowledge base (knowledge creating institutions and programs). Our objective in both cases is to identify functional and spatial clusters of activity that are legitimate existing or potential strengths in the region *vis-à-vis* the broader U.S. economy.[7] We define the areas of *overlap* between the industry and the knowledge/innovation strengths as Appalachia's unique *technology clusters*.

The methodology is based on a strategy of triangulation. Given the myriad plausible ways that high-tech activity might be defined, measured (in terms of quantity), and assessed (in terms of quality), we opt to use multiple data sources, classification schemes, and indicators to screen locations. The logic is that we can be more confident of the strength and depth of the science and technology base of a given Appalachian sub-region if it stands out along several science and technology dimensions.

Figure 3
Study conceptual framework & report organization



7. There is a significant difference between relative and absolute analyses of the region's strengths. In the context of university R&D strengths, the relative approach implies an explicit assessment of Appalachian universities against an outside referent (e.g., a U.S. benchmark). An absolute approach would simply identify the key R&D strengths within and around Appalachia itself. In the case of the former, it is possible that no strengths would be identified. In the case of the latter, the top disciplines in the region — irrespective of their position in a national ranking — would be highlighted. A relative analysis is far superior to an absolute one from a policy perspective since Appalachian businesses, universities, colleges, and labs are not competing solely with each other, but also with entities elsewhere in the United States.

In Section 2 we first identify geographic concentrations of private sector employment in technology-intensive industries, broadly construed. We then reorganize those industries into groups based on an analysis of potential buyer-supplier linkages and similarities in production technologies. The groups of linked and related industries (or value-chains) become the units of analysis for a second look at the geographical pattern of employment in the region. Analysis of the spatial distribution of science and technology occupations provides further evidence of industrial technology assets. Overlaying the industry and occupational employment data allows us to highlight and describe the heaviest concentrations of technology-intensive industrial activity.

Section 3 documents the region's strengths from the perspective of knowledge infrastructure: science, innovation, and, to a more limited extent, education and training. It analyzes university research strengths by discipline, the location and size of federal (or federally-funded) research laboratories, the spatial and functional distribution of utility patents and federal grants for innovation and R&D (e.g. Small Business Innovation Research, or SBIR, grants), the incidence of state-supported technology initiatives, and the extensiveness of science and engineering training in the region's network of teaching universities and community colleges.

Section 4 combines the findings from Sections 2 and 3 to identify localized concentrations where technology-intensive industrial and knowledge creation assets overlap within specific functional areas. Those regions, which we label *technology clusters*, are places where a moderately to highly sophisticated knowledge infrastructure is joined with a substantial related industrial base. As such, they are natural first candidates for development policy initiatives designed to increase the general complement of technology activity in Appalachia. Section 4 concludes by discussing the policy implications of the findings and suggesting actions state and local governments can take to further explore and nurture the technology clusters, even given uncertainty about what elements of the regional knowledge infrastructure contribute most directly to traditional economic development aims (such as job growth). We also discuss the need for further research, especially with respect to documenting sub-specializations within identified clusters and assessing the general performance of the clusters over time.

2 Appalachia's High-Tech Industrial Base

Rather than utilize a single definition and measure of high-technology industrial activity, we characterize Appalachia's industrial base by synthesizing findings generated with three kinds of related information:

- The location of employment by sectors classified according to three levels of technology intensity;
- The location of employment in eight high-tech value-chains, where each value-chain is a group of linked technology-intensive industries as revealed by an analysis of 1992 input-output patterns;
- The location of science and engineering workers in thirteen technology categories.[8]

In the cases of sectoral employment and value-chain employment, we use county-level data and statistical measures of spatial association to identify unique multi-county areas where technology-related activity is significantly concentrated.[9] We cannot use the same approach for the occupation analysis since data on science and engineering workers are available only for metropolitan areas. Thus an exact screening of individual counties based on the three measures is impossible. Nevertheless, we produce graphic overlays of the results to aid identification of those sub-regions within and along the border of Appalachia where technology-related activity is especially pronounced. Concepts, measures, and data sources utilized in this section are summarized in Table 2.

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8. There is no single widely accepted means of characterizing the geography of a region's technology-intensive industrial base. Standard definitions of high-technology industry are necessarily problematic, secondary data sources are limited (often representing some sectors better than others), and government-defined sectoral definitions are imprecise. While high-technology industries might be viewed as those sectors undertaking significant R&D or employing scientists and engineers (the "input" view), definitions based on the technology-intensity of the production process (e.g., the adoption of advanced production machinery and methods; the "process" view) or the complement of technology in the final product (the "output" view) are equally useful in various research and policy contexts.

9. We also use ZIP codes as a unit of analysis in the case of high-tech employment.

Table 2
Study measurement of high-tech industrial activity

Concept	Classification	Variable	Year(s)	Concentration measure	Areal unit	Data source
Technology-intensive industry	Three levels: Very technology-intensive, moderately technology-intensive, somewhat technology-intensive; from U.S. Bureau of Labor Statistics	Industry employment	1989, 1998	Location quotient, *G* statistic	Counties, zip codes	Confidential ES-202 series, U.S. Bureau of Labor Statistics
Value-chains	Eight value chains developed via an input-output analysis of buyer-supplier patterns among high-technology sectors	Industry employment	1989, 1998	Location quotient, *G* statistic	Counties, zip codes	Confidential ES-202 series, US Bureau of Labor Statistics; 1992 benchmark input-output accounts, U.S. Bureau of Economic Analysis
Scientists & engineers	Scientific, engineering, and engineering technician ccupations	Occupational employment	1999	Location quotient	Metro areas	U.S. Bureau of Labor Statistics Occupational Employment Survey

We recognize that even with the use of varying industry and occupational classification schemes, our approach may obscure some important underlying industrial strengths in advanced technology. Our approach is a compromise between the obvious desirability of a highly detailed county-by-county investigation and the practical need for a methodology that is manageable for a large and diverse 406-county region. Our objective is to shed light on the broader spatial pattern of technology-oriented activity in Appalachia, to identify focus areas for strategic policy design, and to derive a set of sub-regions that can be subjected to more detailed investigation.

2.1 Technology-Intensive Industry Employment

We begin by identifying spatial concentrations of private sector industry employment by grouping high-tech sectors into three categories based on their utilization of scientists/engineers and volume of R&D spending: very technology-intensive (VTI), moderately technology-intensive (MTI), and somewhat technology-intensive (STI).[10] The specific SIC codes included under each category are reported in Appendix Table 1. The following gives a broad (and non-exhaustive) indication of the components of each group:

- VTI sectors: Pharmaceuticals, computer and communications equipment, aircraft, computer programming services and software, engineering services, commercial and noncommercial research houses, and testing laboratories;
- MTI sectors: Industrial chemicals, plastics, electronic components, vehicles, medical instruments, general hospitals, and medical and dental labs;

10. The classification, which is from the North Carolina Employment Security Commission as originally utilized in NCACTs 1995, was based on early BLS studies of the proportion of scientists and engineers by sector and National Science Foundation data on the conduct of R&D by sector (personal communication with Dr. Walter Plosila, former executive director of the North Carolina Alliance for Competitive Technologies).

- STI sectors: Miscellaneous chemicals, engines, machinery, household appliances, electrical equipment, truck and bus bodies and trailers, medical appliances and supplies, and miscellaneous communications services.

Data are from the confidential unsuppressed Unemployment Insurance Data Base (UDB) of the U.S. Bureau of Labor Statistics, obtained with special permission.[11] The UDB data, which contain employment and wage figures by establishment for all fifty states, permit us to take a fine-grained look at employment patterns even in very small counties. Publicly available sources of employment data, such as *County Business Patterns*, contain significant data suppression for detailed industries in small counties, either limiting the analysis to aggregated industries or requiring data estimation schemes that introduce unknown error. Geographic identifiers in the UDB also permit the use of alternative spatial units of analysis. We compare results using both counties and ZIP codes in order to minimize the potential bias that can result from examining geographical patterns using arbitrarily shaped areal units.[12]

We use simple county-level location quotients as well as a measure of spatial association called a *G* statistic to identify localized concentrations of activity. While a location quotient indicates a concentration of activity within a single county that is relatively high compared to the national average, the *G* statistic helps reveal broader multi-county areas where technology-related activity is especially pronounced. The *G* works by analyzing the full multi-county spatial distribution of values of a given indicator, such as high-tech employment, to detect where high and low values of the indicator are clustered together. The details of the location quotient and *G* calculations are described in the Methods Appendix.

Because the impacts of neither technology-oriented industries nor knowledge infrastructure respect jurisdictional boundaries, the study area includes the 406 counties under the policy jurisdiction of

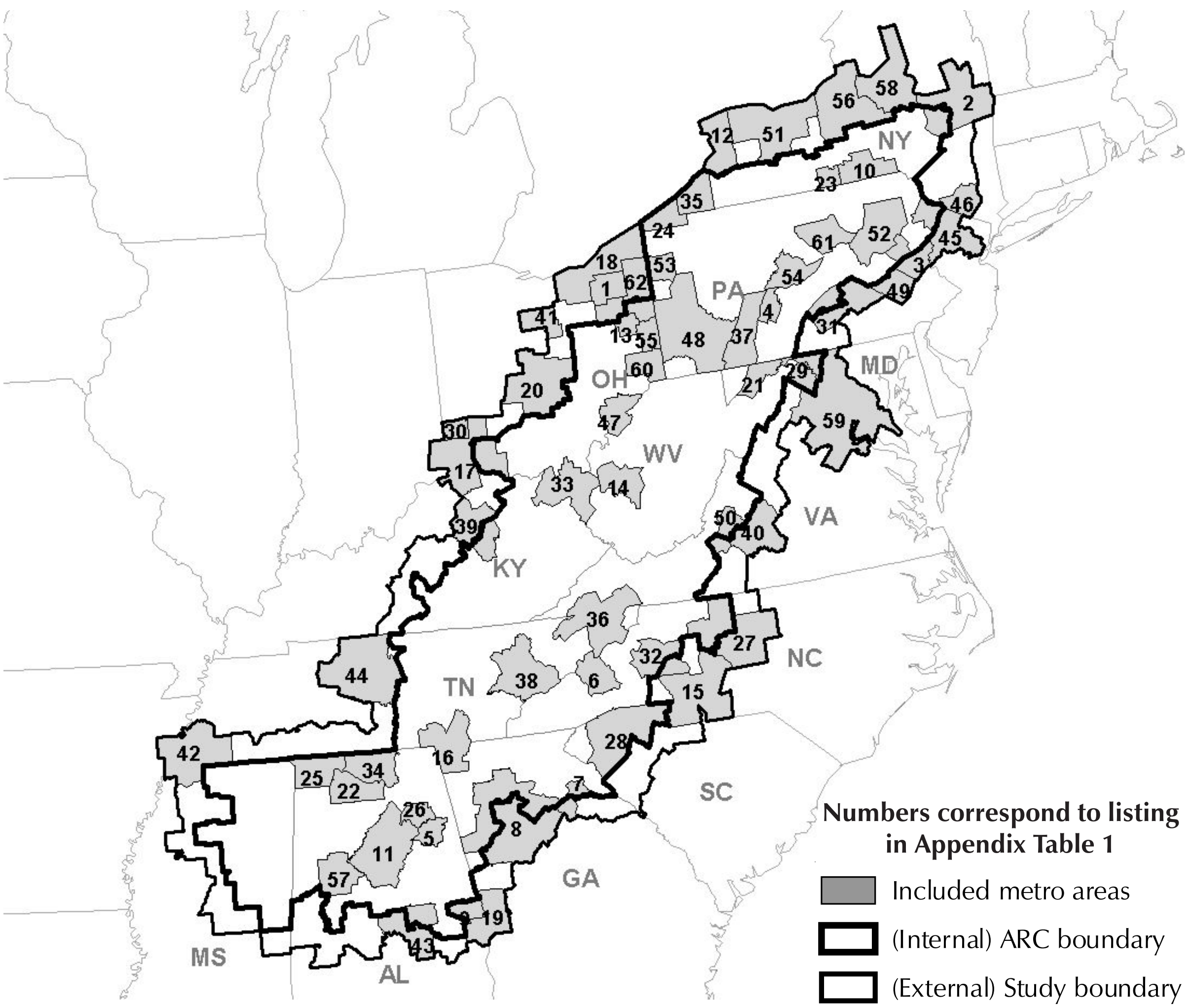
11. The ES-202 file reports employment and wage data for all firms subject to federal and state employment security law, with only the very smallest enterprises and sole proprietorships excluded. At the time of study, 1998 was the most recent year available, with reliable data stretching back to 1989. The UDB data, along with the BLS' new Longitudinal Establishment Microdata (or LDB), are described in Pivetz, Searson *et al.* 2000. Strengths and limitations of BLS ES-202 data are discussed generally in White, Zipp *et al.* (1990) and Davis, Haltiwanger *et al.* (1996).

12. We use counties as the primary spatial unit because of the stability of their boundaries over time, their roughly similar size within the study region, and the relative accuracy with which the ES-202 data could be aggregated to this unit. For the most part, counties are large enough to reflect a relatively homogenous economic unit, but small enough to capture local specializations. Yet counties are still an arbitrary unit of analysis for measuring economic interactions; county boundaries were developed independent of the concentrations of economic activity we are attempting to identify. This creates a unique methodological dilemma known as the modifiable area unit boundary problem (MAUP). MAUP implies that a redrawing of spatial boundaries (or altering the spatial aggregation) on which a given analysis is based could very well generate different results (Fotheringham and Wong 1991; Amrhein 1995; Wrigley 1995). To offset the possibility of MAUP error at the county level, we conduct supplementary analyses using approximated ZIP code boundaries. ZIP codes are typically much smaller than counties, especially in urban areas, and help to pick up areas of tight spatial concentration that get "washed-out" at the county level.

the Appalachian Regional Commission along with a border area of counties and metropolitan areas roughly adjacent to the ARC region.[13] Figure 4 depicts both the ARC and broader study boundaries; as well all included metropolitan areas. Note that metro areas with at least one county either adjacent to or within the ARC region are included. All 62 metropolitan areas in the study area are listed in Appendix Table 2 along with a code that identifies their location on the map in Figure 4.

Although the VTI, MTI, and STI sectors are too aggregated to draw substantive conclusions about localized specializations, they do provide an indication of the general functional and spatial distribution of high-tech activity in the region. In the introduction to this report, we noted that the VTI sector is under-represented in Appalachia compared the U.S. as a whole, while its employment growth during

Figure 4
Study area, Appalachia and border region



13. Also included are eight independent cities in Virginia. The Census Bureau gives a separate county level FIPS code to these cities and thus they are treated as independent entities in our spatial analysis. Note that, in some cases, counties wedged between two adjacent counties were also included in the border region.

the 1990s was sluggish (see Table 1). Likewise, although Appalachia is slightly over-represented compared to the nation in the STI sector, employment in STI industries are barely expanding (a mere 0.5 percent net growth in employment between 1990 and 1998). Indeed, the trends suggest that Appalachia's high-tech industrial base is shifting toward industries in the MTI category. MTI industries as a group posted the fastest rate of job growth among the three sectors between 1989 and 1998 (17 percent growth in Appalachia compared to 14.1 percent at the national level). They also account for the largest share of technology-related employment in the region (at 7.3 percent of private sector activity). As we show below, MTI concentrations are also well represented throughout northern, central, and southern Appalachia.

To characterize the spatial distribution of VTI, MTI, and STI employment, we calculated our measures of concentration (the local *G* statistic and location quotient) several different ways. First, we calculated employment location quotients for each county for 1998. Next, we computed *G* statistics first using counties and then ZIP codes as the units of analysis, with 1998 employment as the variable of study. Finally, we calculated county-level local *G* statistics with the change in employment between 1989 and 1998 as the variable of interest. Figures 5–7 overlay the results, highlighting only significant values for each measure. In the case of the *G*, highlighted values are those that are statistically significant at the 95 percent level. In the case of the location quotient, highlighted values are those in excess of 1.1. Employment location quotients appreciably greater than 1.0 indicate that there is a higher share of the given activity in the study county than the U.S. as a whole (thus suggesting a relative specialization in that county).[14]

Figure 5 shows that substantial multi-county concentrations of VTI employment in the region are very few (as represented by the significant *G* values for counties and ZIP codes). They are found in the Binghamton, Knoxville, Huntsville, and greater Atlanta metro areas. There are no concentrations of VTI employment growth within Appalachia, though there is some activity along its northwest border in New York (near Rochester) and its northeastern border (associated with the Albany area, greater New York City, and Washington DC).

By contrast, Figure 6 reveals roughly fifteen significant concentrations of MTI employment scattered throughout the region, with the most extensive in the vicinities of Charleston, WV (and extending north to Parkersburg), Pittsburgh, Johnson City, Birmingham/Tuscaloosa, and Greenville-Spartanburg. Employment growth in the MTI sector over the 1990s was especially concentrated in the Birmingham/

14. Many of the counties posting significant location quotients or *G* values are in metro areas. For convenience, Appendix Table 3 indicates whether evidence of spatial concentration was determined in at least one county or ZIP code in each metro area in the study region. The table should be interpreted cautiously. It does not indicate a concentration for an entire metro area but rather for one or more counties/ZIP codes within given metro areas.

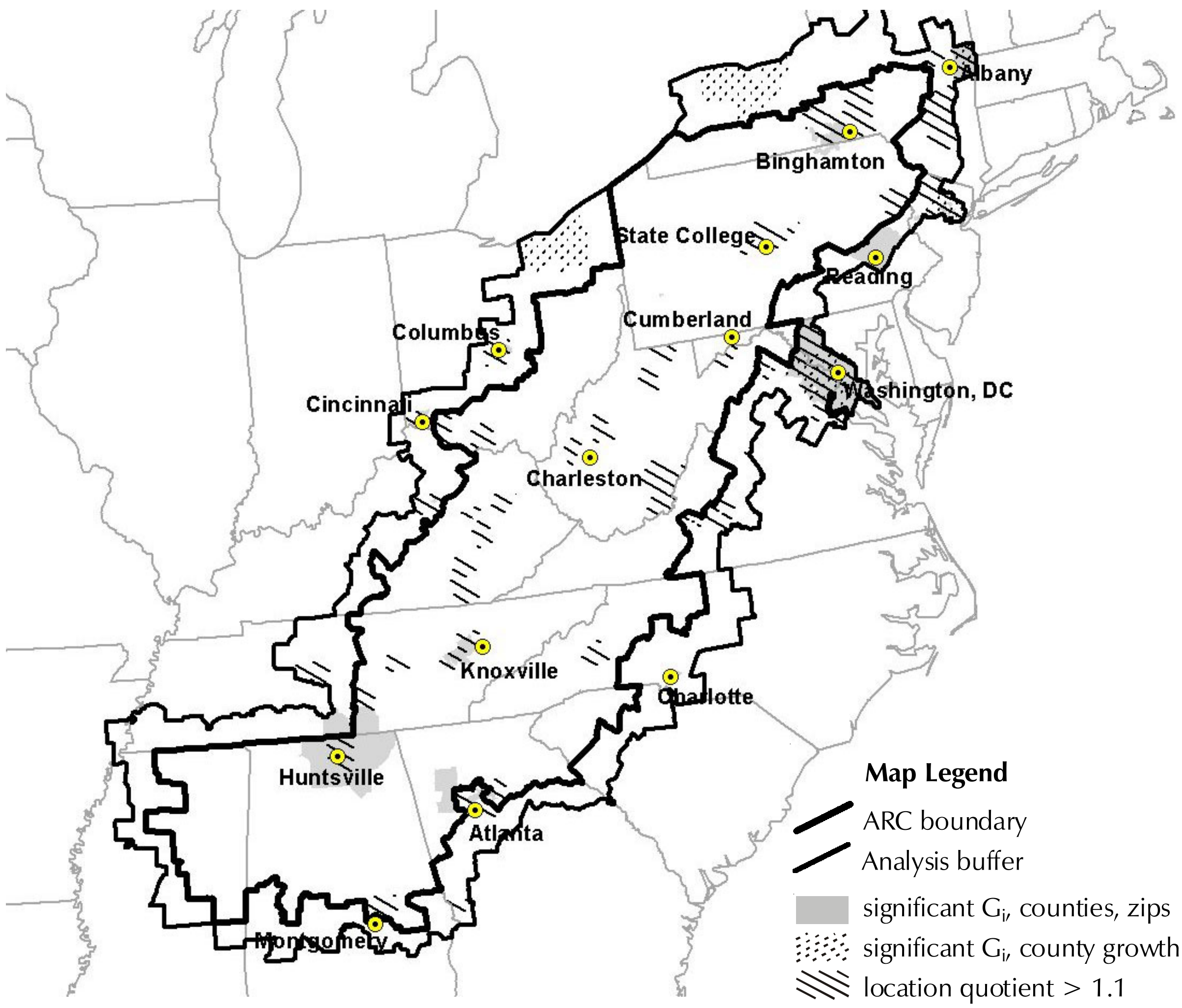
Tuscaloosa area, as well in the Carolinas (Asheville, NC and Greenville, SC). Border concentrations of MTI activity are found in New York (Buffalo, Rochester, Albany, Newburgh), Akron, and central Kentucky.

While MTI concentrations are distributed throughout Appalachia, concentrations of STI employment and employment growth are oriented toward the north (in New York, Pennsylvania, and Ohio) and the south (Tennessee, the Carolinas, Georgia and Alabama). Interestingly, there are no substantial STI concentrations in West Virginia or eastern Kentucky (see Figure 7). Indeed, only a few counties in those areas even post location quotients above 1.1.

2.2 High-Tech Value-Chains

Given a general sense of how Appalachia's industrial high-tech base is oriented toward sectors that are moderately to somewhat technology-intensive, we next utilized a different industrial classification scheme that acknowledges functional relationships between sectors to consider the region's specific strengths by industry. Specifically, we re-sorted the four-digit SIC components of the STI, MTI, and VTI

Figure 5
Spatial concentration: Very tech-intensive industries, 1998

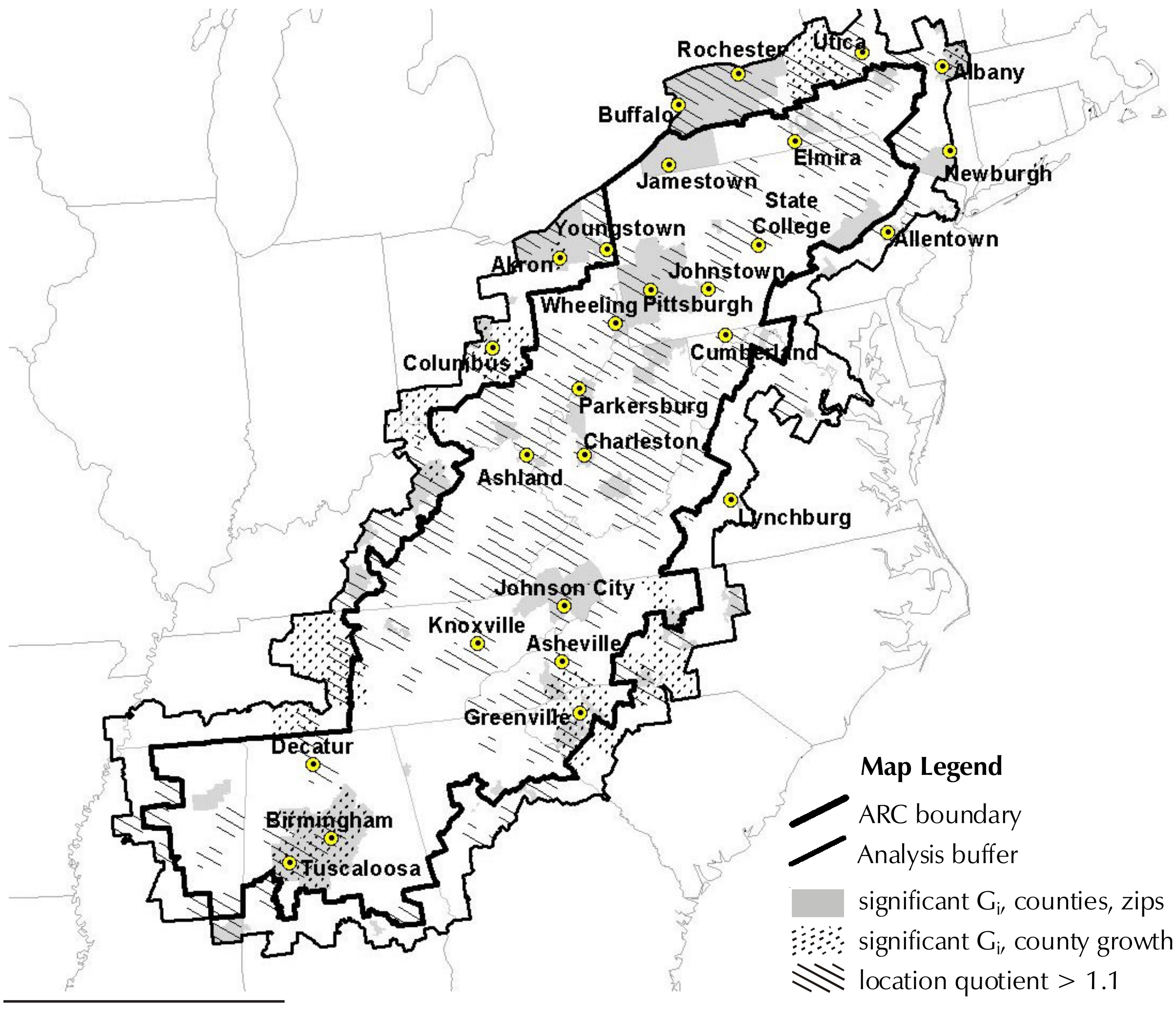


sectors into new groups that represent distinct value-chains, or groups of high-tech industries that are significant trading partners.

The value-chains are based on a detailed analysis of national 1992 input-output patterns and, therefore, represent the core technology-intensive buyer-supplier chains in the U.S. economy.[15] The details of their derivation are summarized in the Methods Appendix. Each of the eight chains, which are listed in Table 3, is comprised of between eight and thirty diverse four-digit SIC codes (see Appendix Table 4). For example, the motor vehicles value-chain includes chemicals, machinery, electronics and transportation equipment industries. The value-chains are not mutually exclusive since some sec-

Figure 6

Spatial concentration: Moderately tech-intensive industries, 1998



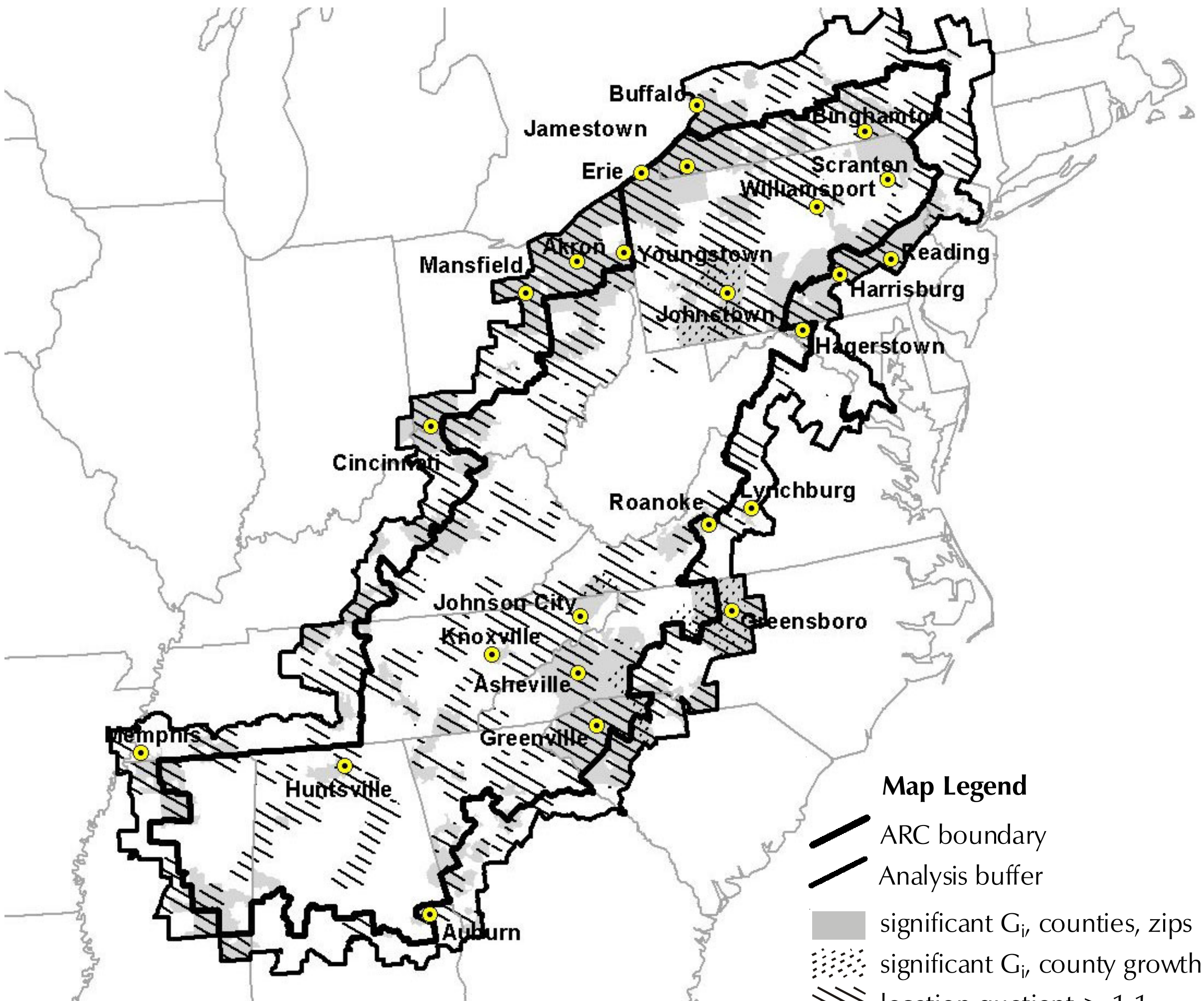
15. The technology value-chains are derived from a statistical analysis of national input-output data. Input-output data provide a useful characterization of trading patterns and general technological similarities among all U.S. industries, but with an emphasis on manufacturing. The value-chains are therefore groups of technologically intensive industries that constitute final market producers and their first, second, and third tier supplier sectors. Their derivation is discussed in the Methods Appendix; a discussion of general issues related to the identification of linked industries is available in Bergman and Feser 1999.

tors are linked to multiple industries, a feature that reinforces their characterization of interdependence in the economy.[16] The high-tech value-chains are a good starting point for assessing unique industrial specializations in Appalachia since they go beyond simple sectoral definitions to include groups of industries that share similar competitive pressures and, in some cases, utilize similar production technologies.

In employment terms, the largest high-tech value-chains in Appalachia are information technology and instruments, communications software and services, chemicals and plastics, and motor ve-

Figure 7

Spatial concentration: Somewhat tech-intensive industries, 1998



16. There are 149 four-digit SIC codes classified as very, moderately, or somewhat technology-intensive in Appendix Table 1. In the input-output analysis, nineteen of those sectors failed to link to any other major groups of sectors. The largest of these in terms of employment in Appalachia and the U.S. is general hospitals. Twelve of the nineteen sectors are classified in the STI sector; only one (noncommercial research organization, SIC 8733) is classified in the VTI sector. Because it is questionable whether general hospitals can be regarded as high-tech industries, and because most of the remaining eighteen sectors were in the low-technology category, the nineteen "unlinked" industries are not included in the value-chain analysis.

hicles (see Table 3). However, both information technology/instruments and communications software/services are significantly under-represented in the region compared to the U.S. Over-represented chains — arguably Appalachian specializations — are chemicals/plastics and industrial machinery (see Figure 8). The two fastest growing chains in Appalachia during the 1990s were communications software/services and motor vehicles. The latter has become an important industrial strength in the region as automotive production and related supplier industries have shifted south. The emergence of end-market vehicle production in Ohio, Kentucky, Tennessee, South Carolina, and Alabama has undoubtedly helped drive an increase in vehicle-related employment in Appalachia of nearly 34 percent between 1989 and 1998, well above national growth of 11 percent. In contrast, even at 35 percent over the period, employment growth in the Appalachian communications services/software value-chain fell well below the national rate of growth (at 56 percent).

Table 3

Technology-intensive value-chain employment & wages, 1989, 1998

United States*	Employment				Payroll		
Value-chains	1989 (000's)	1998 (000's)	% private sector '98	% Change '89-'98	1998 (Millions $)	% private sector '98	Average wage $
Chemicals and plastics	1,218.7	1,384.8	1.3	13.6	59,213	1.8	42,760
Information technology & instruments	2,887.5	3,573.0	3.4	23.7	202,588	6.1	56,700
Industrial machinery	550.1	568.0	0.5	3.3	23,040	0.7	40,564
Motor vehicles	1,375.8	1,523.3	1.5	10.7	70,242	2.1	46,111
Aerospace	1,097.2	848.8	0.8	-22.6	42,557	1.3	50,136
Household appliances	94.6	91.5	0.1	-3.2	3,233	0.1	35,330
Communication software & services	1,877.2	2,918.6	2.8	55.5	163,049	4.9	55,866
Pharmaceuticals & medical technologies	840.9	982.7	0.9	16.9	49,930	1.5	50,807
Total private sector	96,029.3	104,258.3	100.0	8.6	3,310,187	100.0	31,750

Appalachia	Employment				Payroll		
Value-chains	1989 (000's)	1998 (000's)	% private sector '98	% Change '89-'98	1998 (Millions $)	% private sector '98	Average wage $
Chemicals and plastics	119.0	129.7	1.5	9.0	5,107	2.3	39,377
Information technology & instruments	151.0	167.2	2.0	10.7	6,494	3.0	38,852
Industrial machinery	65.7	60.0	0.7	-8.6	2,276	1.0	37,926
Motor vehicles	90.7	121.4	1.4	33.9	4,356	2.0	35,884
Aerospace	40.7	40.1	0.5	-1.4	1,572	0.7	39,222
Household appliances	5.2	5.7	0.1	10.7	171	0.1	29,965
Communication software & services	98.2	132.4	1.6	34.8	5,845	2.7	44,140
Pharmaceuticals & medical technologies	54.1	56.9	0.7	5.1	2,286	1.0	40,194
Total private sector	7,292.4	8,443.1	100.0	15.8	219,867	100.0	26,041

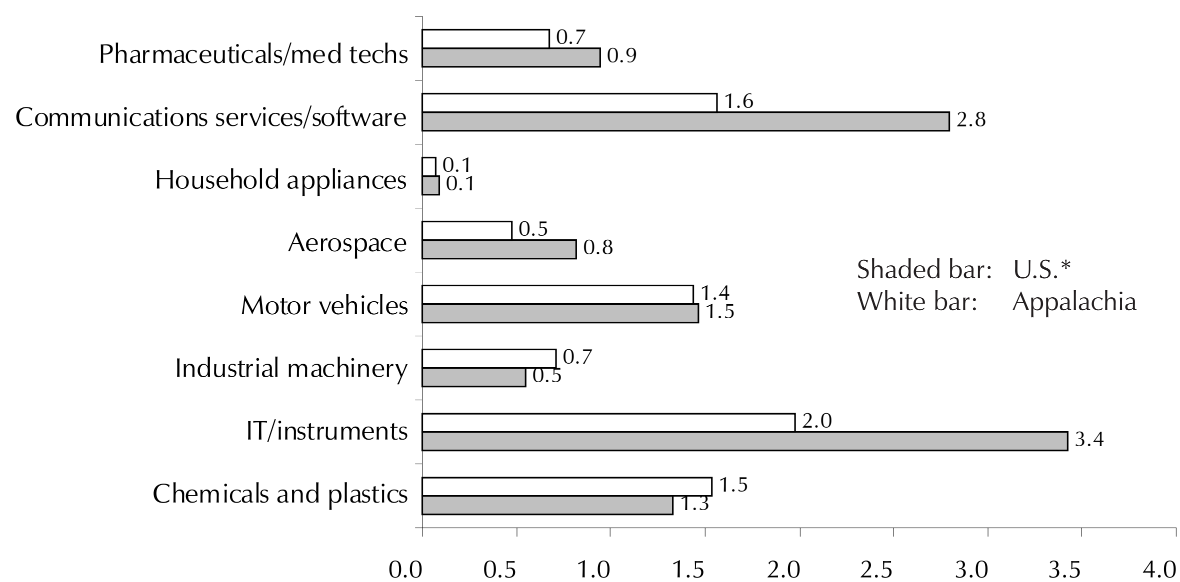
Source: U.S. Bureau of Labor Statistics, ES-202 files. *U.S. figures exclude Alaska, Hawaii, and Wyoming. Appalachia includes only the 406-county ARC region. Value-chains are not mututally exclusive and do not include all technology-intensive industries that make up the STI, MTI, and VTI sectors in Table 1.

As in the case of the STI, MTI, and VTI sectors, we calculated and compared the two different measures of concentration for several different units of analysis (counties, ZIP codes) and variables (employment, employment growth). Figures 9–16 plot the indicators using the same overlay approach.

Evidence of localized clustering in the region is strongest for three value-chains: chemicals and plastics (Figure 9), motor vehicles (Figure 10), and industrial machinery (Figure 11). Sub-regional concentrations of chemicals and plastics employment, in particular, can be found in a large number of locations in Appalachia, including the Pittsburgh area, central and eastern Pennsylvania, West Virginia and Southern Ohio (near Parkersburg and Charleston), northeastern Tennessee, the Carolinas, and central Alabama (Birmingham and Tuscaloosa). In contrast, motor vehicles employment closely tracks the I-71, I-65, and I-85 corridors, putting most of the localized activity along the region's borders. Particularly heavy concentrations with potential spillovers to Appalachia are found in central Kentucky (home of Ford, GM, and Toyota), central Ohio, western North Carolina (a key location for vehicle parts manufacturing) and the Greenville-Spartanburg area (home of BMW). Smaller concentrations are found in northern Pennsylvania, Tennessee, and northern Alabama. Concentrations of industrial machinery employment are particularly heavy in Pennsylvania (Johnstown, Pittsburgh), New York, western Virginia, and an extended region that runs from Charlotte through Greenville-Spartanburg to Atlanta.

The remaining technology value-chains show only limited evidence of localization in the region. As noted above, Appalachia is relatively weak in information technology and instruments. The value-chain (essentially production of IT-related hardware) is concentrated in Binghamton (IBM is the pro-

Figure 8
Percent private sector employment by value-chain, 1998



Source: U.S. Bureau of Labor Statistics. *Excludes WY, AK, & HI.

genitor in this case), State College, and Huntsville (Figure 12). Concentrations of communications software and services are found Pittsburgh, Knoxville, Huntsville, and Atlanta (Figure 13), while aerospace activity is localized in northwestern Pennsylvania (south of Erie in a region anchored by Crawford county), Huntsville, and greater Atlanta (Figure 14). Activity in the aerospace concentration in Pennsylvania is driven primarily by tool and die and precision machinery activities as core suppliers to the aircraft industry.

Localized activity in household appliances value-chain are found in south central Kentucky (with some spillover into the ARC region), Johnson City, Greenville-Spartanburg, and Decatur, Alabama, with key border concentrations in the Canton and Montgomery areas (Figure 15). There are several small areas of geographic concentration of pharmaceuticals and medical technologies activity within Appalachia (Figure 16). They are found mainly in Pennsylvania and northern West Virginia, Tennessee, western North Carolina, western South Carolina, and northern Alabama (Huntsville).

Figure 9
Spatial concentration: Chemicals and plastics value-chain

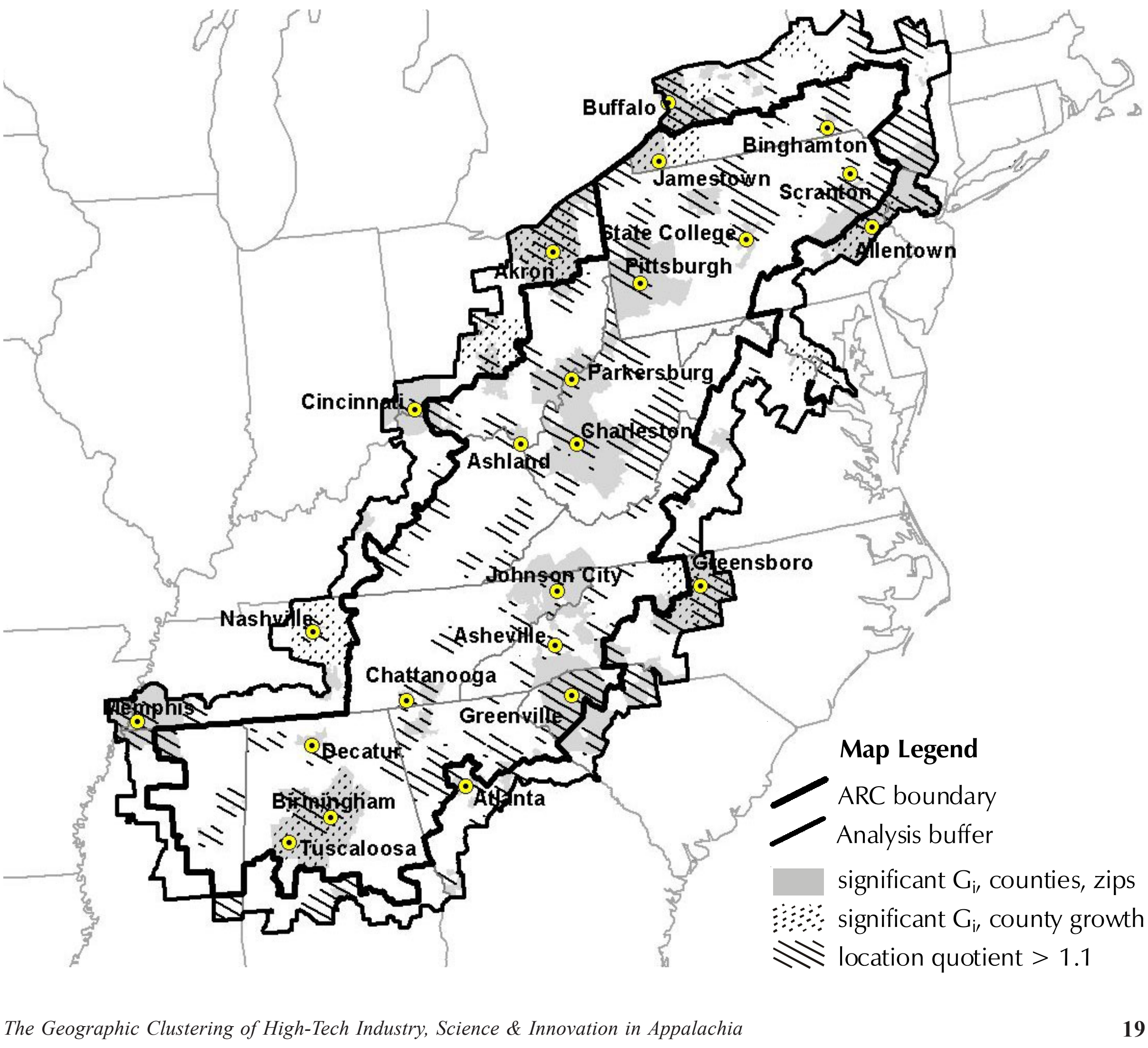


Figure 10
Spatial concentration: Motor vehicles value-chain

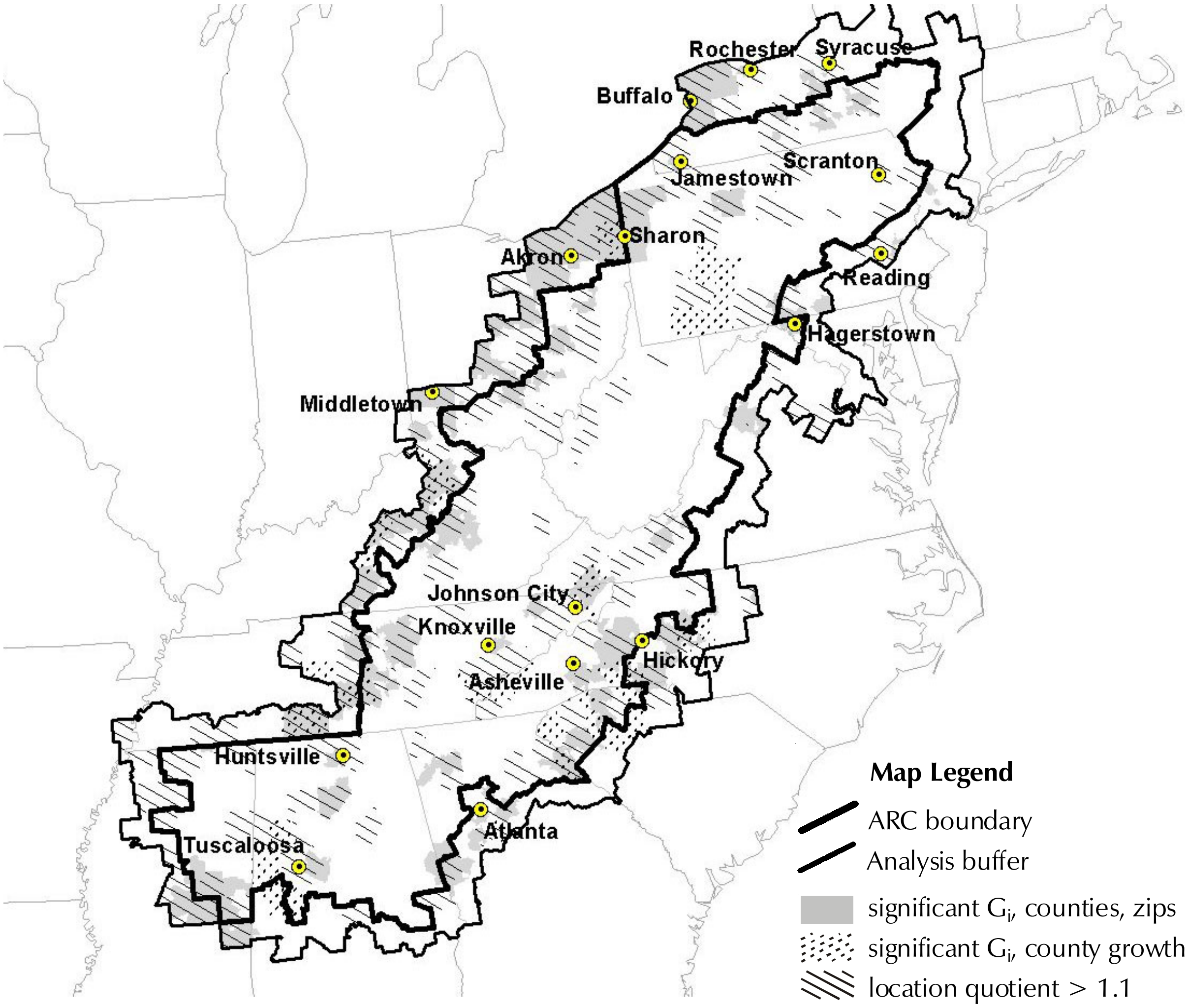


Figure 11
Spatial concentration: Industrial machinery value-chain

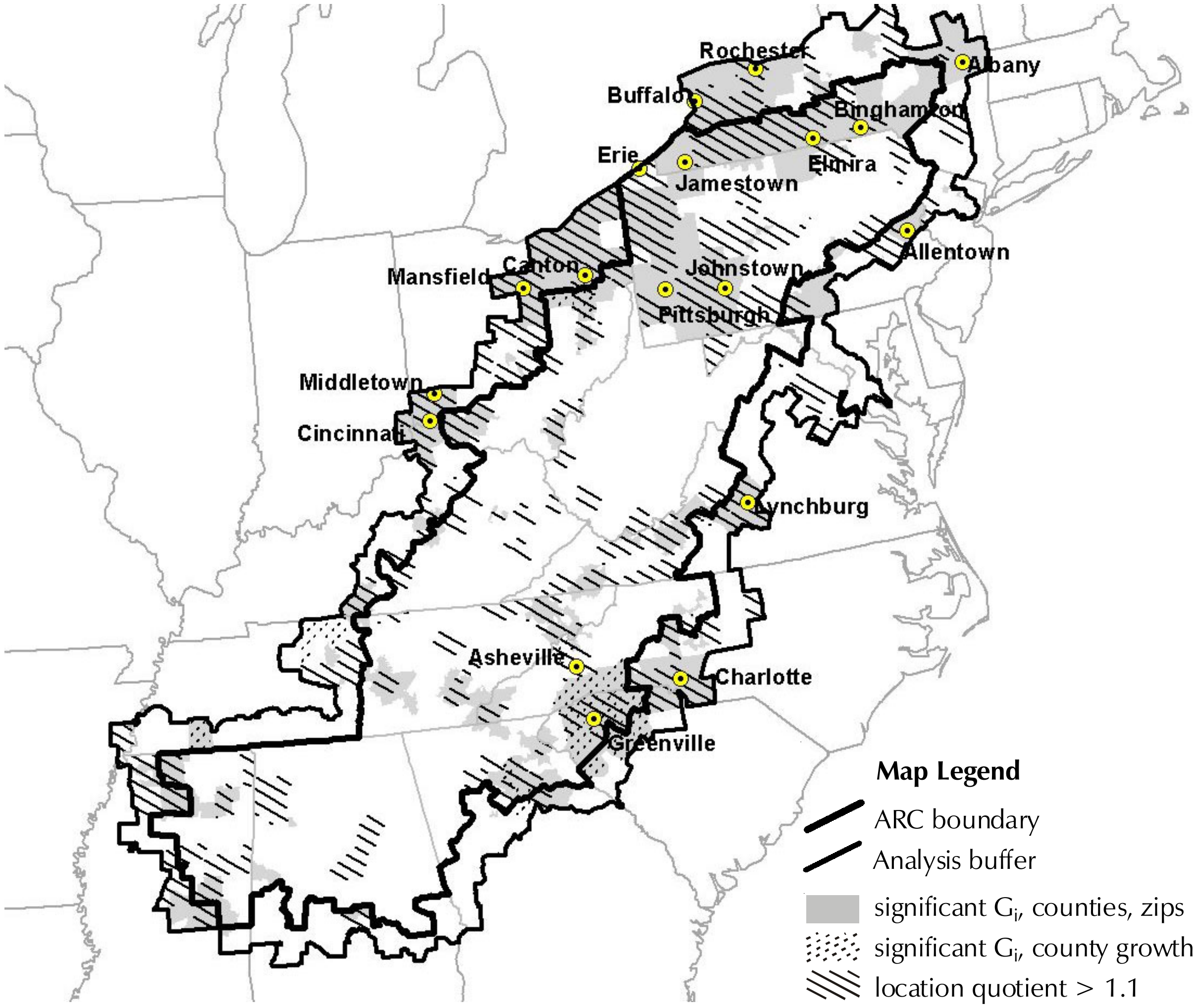


Figure 12

Spatial concentration: Information technology and instruments value-chain

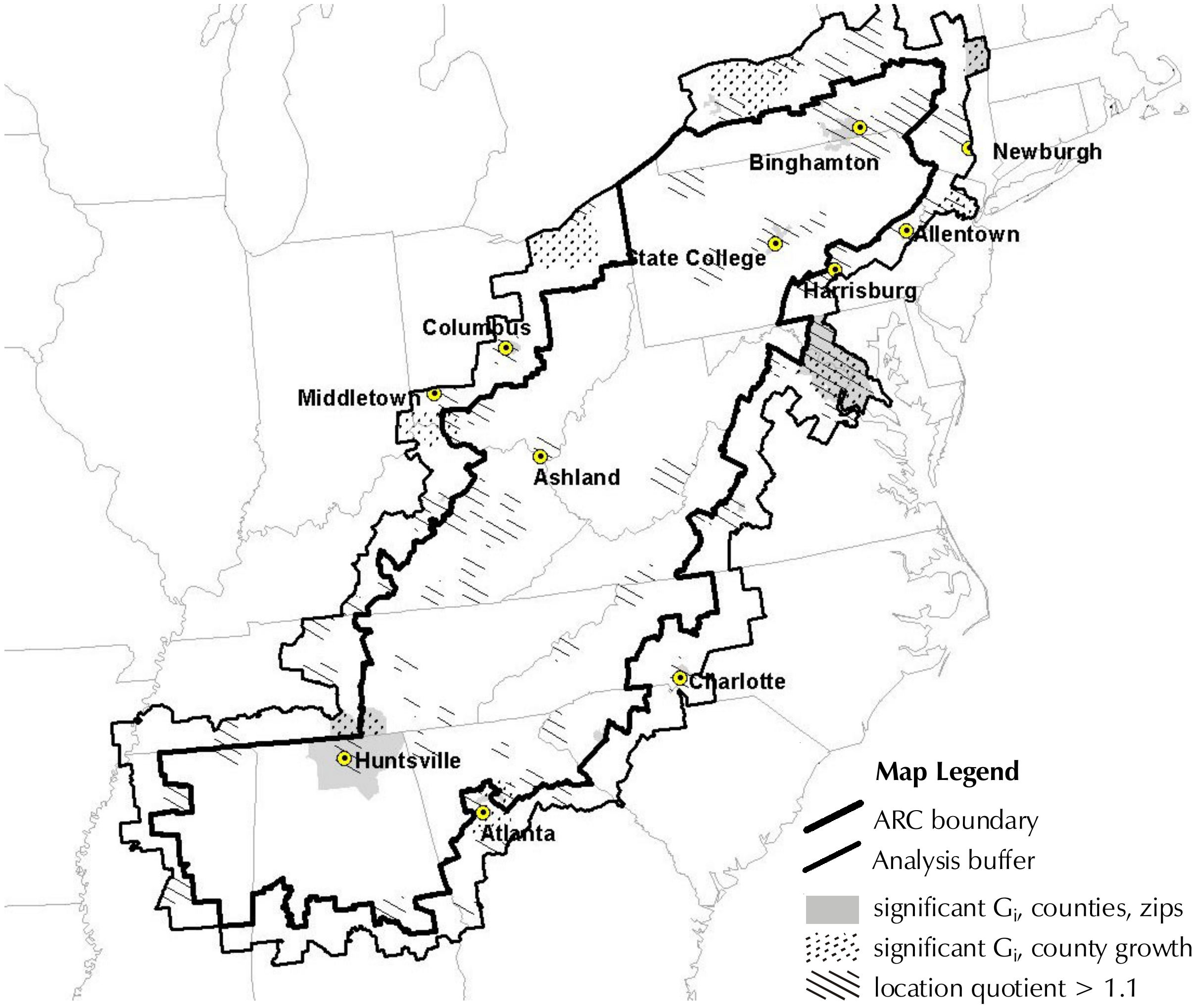


Figure 13

Spatial concentration: Communications services & software value-chain

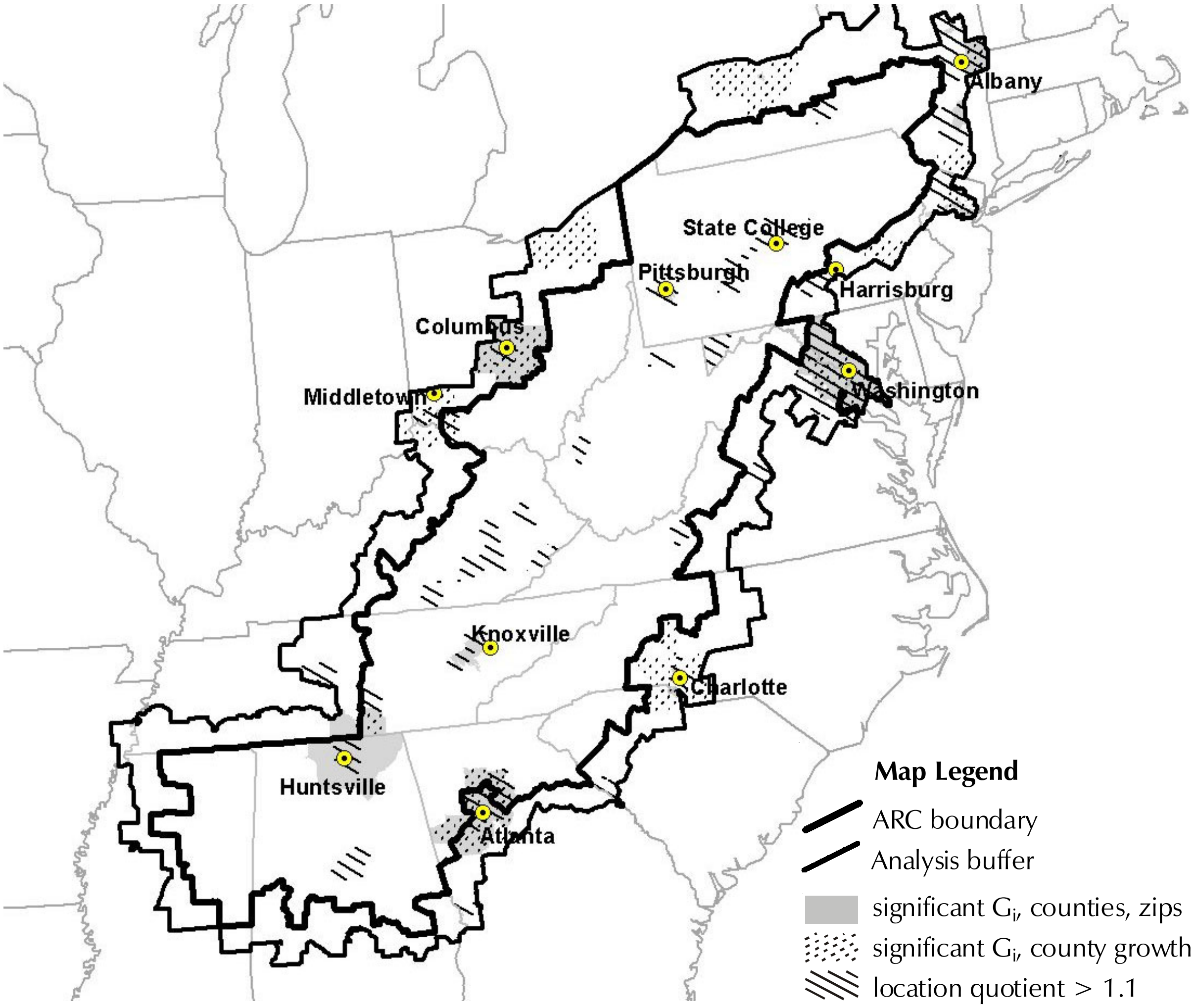


Figure 14
Spatial concentration: Aerospace value-chain

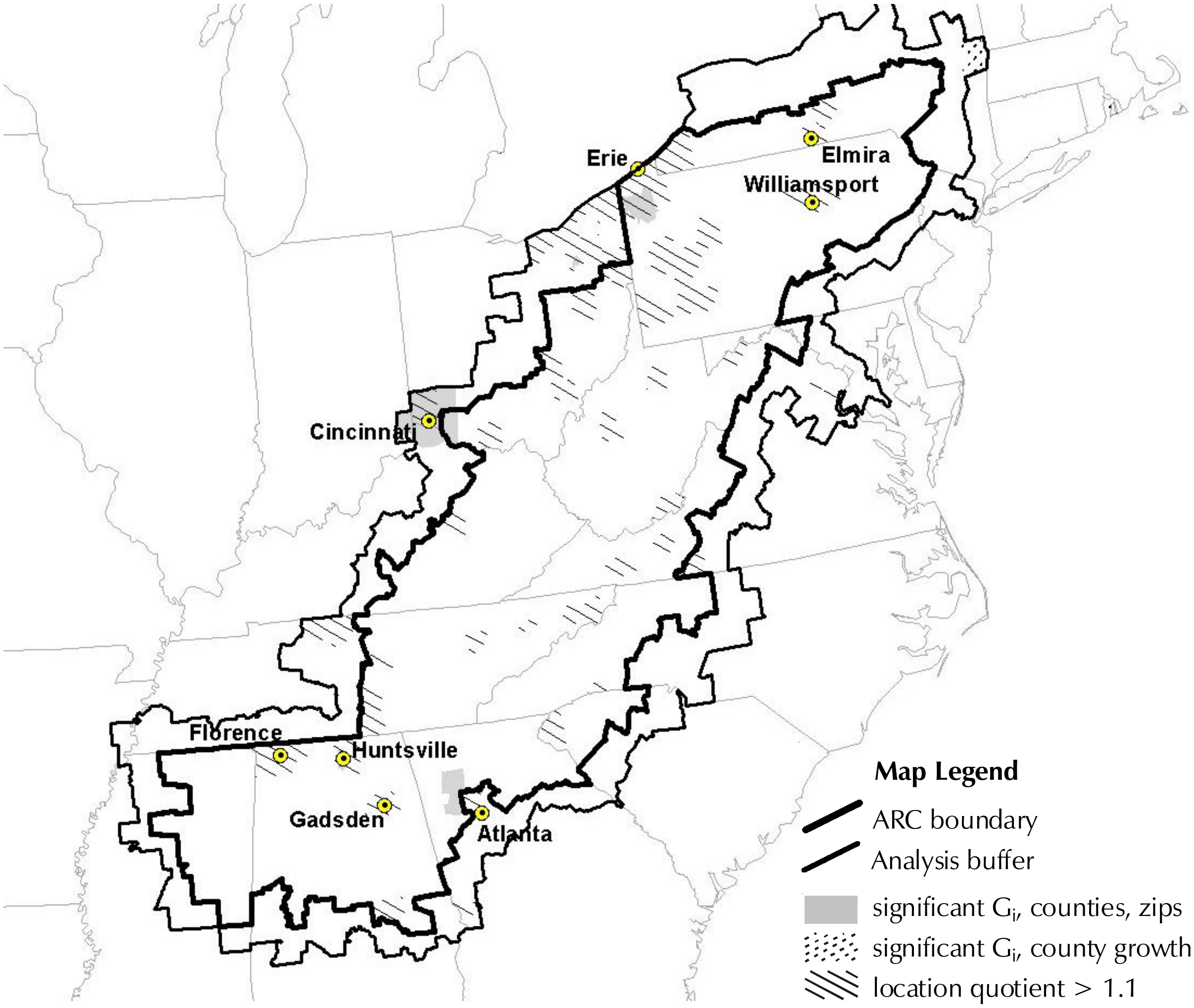


Figure 15
Spatial concentration: Household appliances value-chain

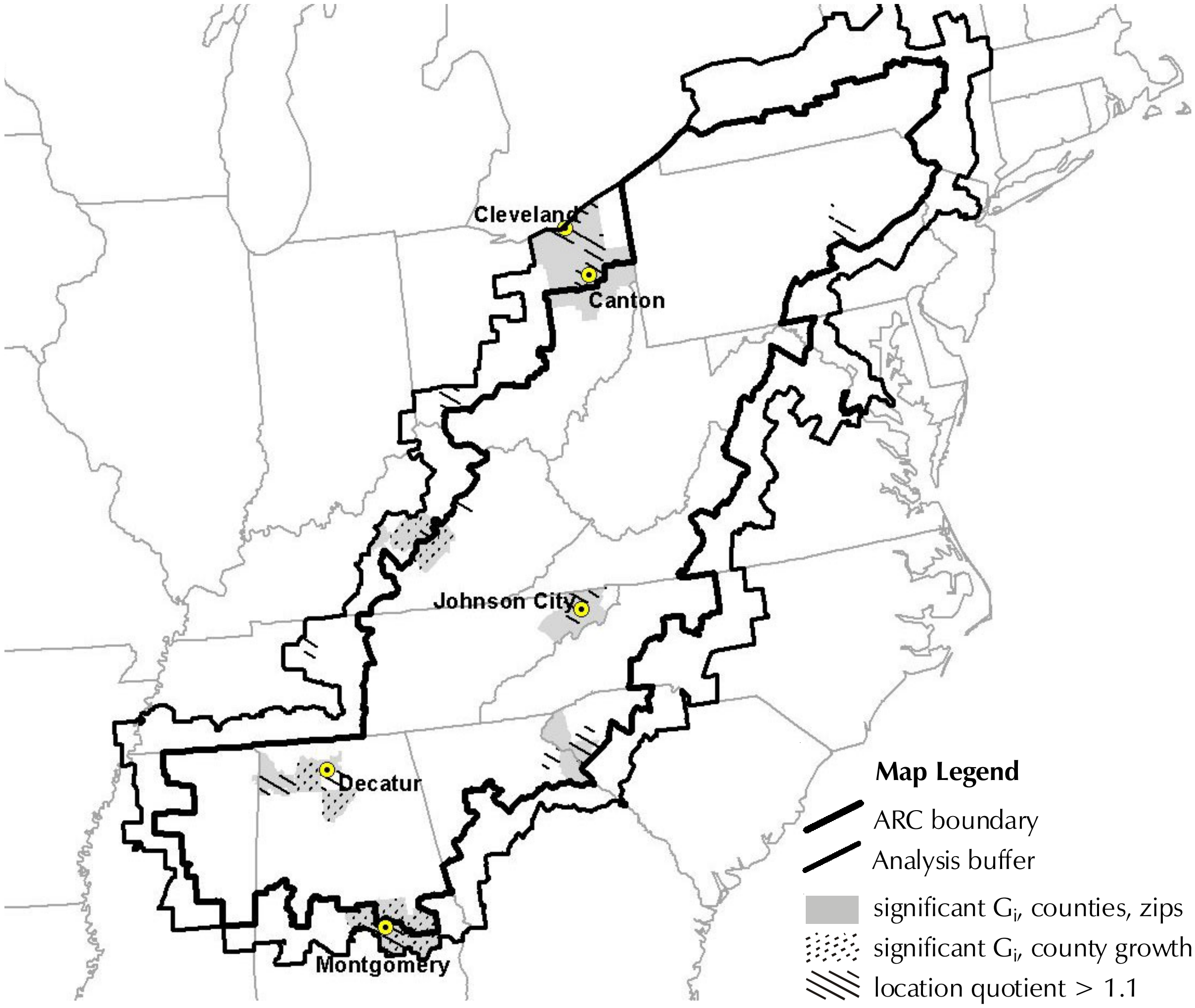
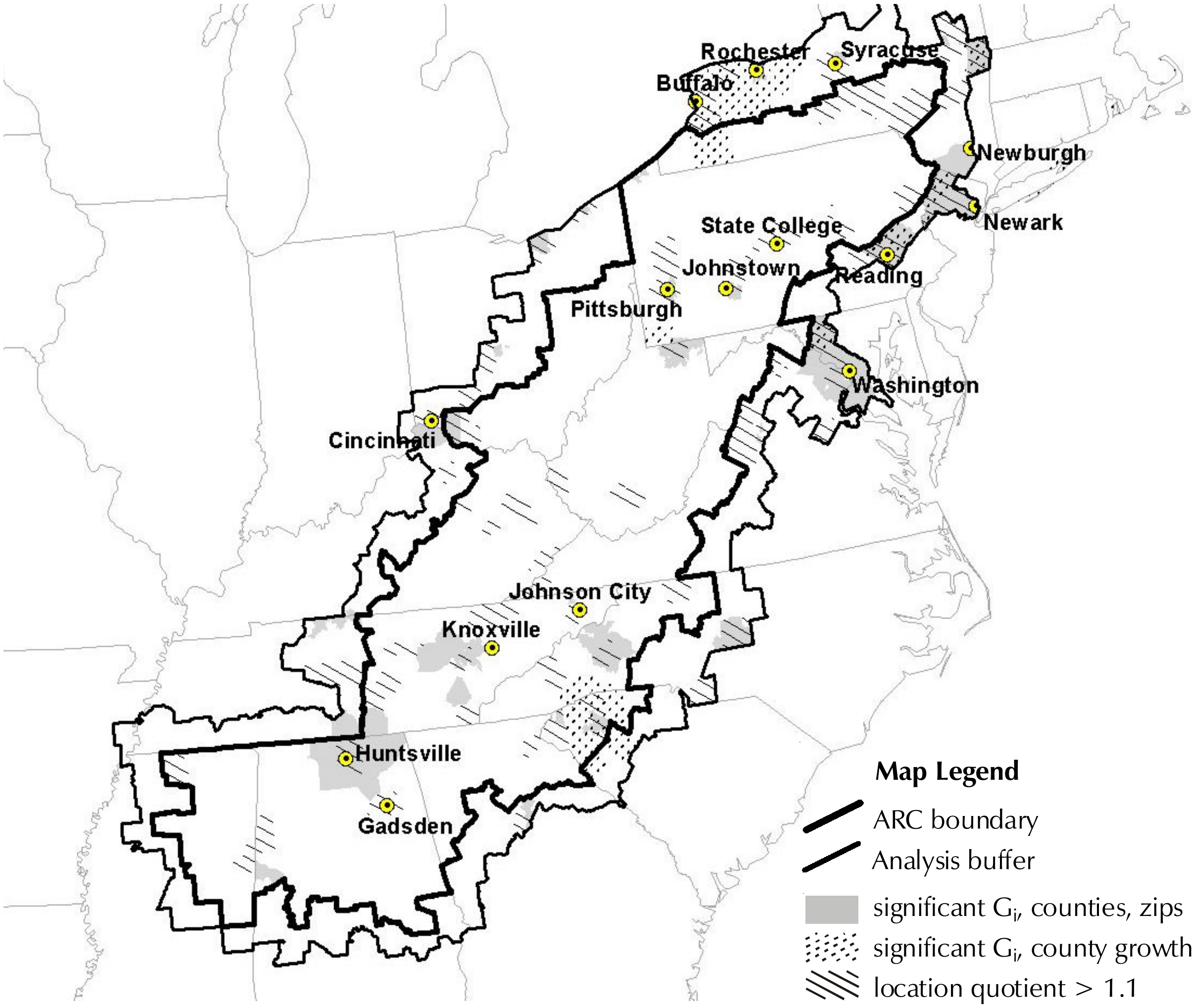


Figure 16

Spatial concentration: Pharmaceuticals and medical technologies value-chain



Appendix Table 5 summarizes these findings by metro area. In terms of a diversity of technology-related industry, there are clearly five leading or "first-tier" metropolitan areas in Appalachia: Binghamton, Greenville-Spartanburg, Huntsville, Johnson City, and Pittsburgh. We found evidence of high-tech concentrations in four or more value-chains in at least parts of each of those cities (seven and six in the cases of Huntsville and Greenville-Spartanburg, respectively). A second tier of cities that are also home to multiple value-chain concentrations include Asheville, Decatur, Erie, Knoxville, and State College, PA. In Section 3, we consider the spatial distribution of patent grants in technology areas that roughly correspond to those of the value-chains, allowing us to eventually compare a measure of productive activity (employment) with innovation.

2.3 Scientists, Engineers, and Technicians

Occupational employment statistics provide a third means of characterizing the location of technology-intensive activity, where the latter is broadened to include both the private and public sectors. Sub-state occupational employment data are available from the U.S. Bureau of Labor Statistics' Occupational Employment Statistics (OES) series.[17] The OES data are available only for metropolitan areas however, forcing us to ignore rural areas and to use only the location quotient measure of concentration. Nevertheless, the metro-level analysis of the region's scientific, engineering and technician workforce is a useful supplement to our analyses of the geography of industry employment and patents.

From the 709 occupations reported in the 1999 OES data, we identified 56 specific science, engineering, and engineering technician occupations. We organized the 56 occupations into thirteen substantive groups that roughly parallel, though are more detailed, than the eight value-chain industries (see Table 4). The 56 included occupations and their match to one of thirteen aggregate categories are reported in Appendix Table 6.[18]

A few of the remaining 653 occupations in the 1999 OES data bear mentioning since the reasons for excluding them from our classification of scientists and engineers helps clarify our objectives. For example, we did not include civil engineers/technicians and opthalmic and dental lab technicians among the 56 science and engineering occupations. The vast majority of individuals employed as civil engineers or health lab technicians are not engaged in science or innovation activities. We also did not include teachers in the various science and engineering fields in the set of 56 S&T occupations. Because there are such a large number of teachers in a broad array of fields (a significant share of whom are

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17. The 1999 OES survey is described in BLS (2001). OES data are accessible directly via the Internet at http://www.bls.gov/oes.

18. We also identified a reduced set of 36 occupations that includes scientists and engineers only (no technicians). Location quotients for scientists/engineers and technicians separately are reported in Appendix Tables 7 and 8.

Table 4

Estimated employment: Scientists, engineers and technicians, 1999

		Employment		Pct share, total sci/eng emp		
Occupational category	Code	US	ARC	US	ARC	ARC LQ
IT scientists, engineers, and programmers	IT	2,407,450	406,900	57.2	65.4	1.04
Mathematicians, statisticians and physicists	Math	73,680	10,900	1.8	1.8	0.91
Agricultural scientists and engineers	AgSci	27,030	640	0.6	0.1	0.15
Biological scientists and technicians	Bio	69,290	5,300	1.6	0.9	0.47
Chemists and chemical engineers	Chem	181,200	25,430	4.3	4.1	0.86
Environmental and resource scientists and technicians	Enviro	190,440	19,700	4.5	3.2	0.63
Medical scientists and engineers	Med	41,260	2,710	1.0	0.4	0.40
Electrical engineers and technicians	Elect	538,510	72,100	12.8	11.6	0.82
Materials engineers and scientists	Matrl	29,930	3,530	0.7	0.6	0.72
Aerospace engineers and technicians	Aero	111,790	7,530	2.7	1.2	0.41
Geoscientists and engineers	Geo	55,460	1,580	1.3	0.3	0.17
Nuclear engineers and technicians	Nucl	12,220	180	0.3	0.0	0.09
Industrial and mechanical engineers and technicians	Indust	468,070	65,820	11.1	10.6	0.86
All scientists, engineers, and technicians		4,206,330	622,320	100.0	100.00	0.91

Source: Occupational Employment Statistics, U.S. Bureau of Labor Statistics. Note: U.S. figures are for entire country (metro and nonmetro). ARC figures are for metro areas only.

engaged primarily in instruction rather than research), they tend to dominate other occupational categories. As an indicator of science and engineering activity, occupational employment loses much of its precision when teachers are added to the mix. The role of post-secondary educational institutions in both teaching and research is considered in Section 3.

As survey-based data, BLS occupation statistics must be used very cautiously. The data for many metro areas, particularly smaller ones, are often incomplete due to inadequate sample sizes and data confidentiality regulations that necessitate suppression or non-reporting. BLS also does not report data for occupations with fewer than 50 workers. The publicly available metro-level data therefore often constitute undercounts for smaller MSAs when they are aggregated up from detailed occupational categories. Yet because data are generally reported for occupations with a substantial number of workers and employing companies, they can still be useful for highlighting significant industrial specializations in various technology areas.

There were some 4.21 million scientists, engineers, and technicians (excluding teachers) employed in the U.S. in 1999, constituting about 3.3 percent of the total workforce (see Table 5). Of those, 2.41 million (or 57 percent of the 4.21 million) were in information technology and related fields. Electrical engineers/technicians and industrial and mechanical engineers/technicians accounted for a respective 13 and 11 percent of the total employed pool of scientists and engineers.

Available BLS estimates for the 62 MSAs in the extended Appalachian study region place the science and engineering workforce at just over 622,000, or about 3 percent of total metro employment.

Again, that figure is likely a modest undercount, given suppressed data and non-reporting in the base data. The science and engineering workforce in the 62 metro areas within and nearby Appalachia appears to be comprised more heavily of occupations in the information technology field. IT scientists, engineers, and programmers constitute an estimated 65 percent of all scientists, engineers, and technicians in the MSAs included in the study.

Table 5 suggests that if Washington, DC is excluded from the analysis, the southern third of the study region is slightly more "science and engineering-intensive" than the northern and central regions, at least as measured by the share of scientists and engineers in the workforce. Indeed, it is notable that absent Washington, the share of scientists and engineers in the metro Appalachian workforce would fall to roughly 2.2 percent, well below the 3.3 percent national average. Table 5 also shows that the metro science and engineering workforce in and nearby Appalachia is evenly split between scientists/engineers and less skilled technicians (each group accounting for about 1.5 percent of the total workforce). Nationwide, less skilled technicians account for a somewhat smaller share of employment in science and engineering occupations.

Table 5

Employment shares: Scientists, engineers and technicians

Percent total employment in each region, 1999

Region	Scientists, engineers, & technicians	Scientists & engineers only	Technicians only
US (Metro and Nonmetro)	3.3	1.8	1.5
ARC MSAs	3.0	1.5	1.5
Northern	2.2	1.1	1.1
Central	4.4	2.3	2.1
Central (w/o Washington, DC)	2.4	1.3	1.1
Southern	2.8	1.4	1.4

Source: Occupational Employment Statistics, U.S. Bureau of Labor Statistics.

Employment location quotients by study MSA for the thirteen science and engineering occupation categories are reported in Table 6 and displayed in Figures 17–19.[19] Relatively few MSAs wholly within Appalachia post location quotients significantly above 1.0 (e.g., >1.25), indicating a specialization in the given technology area. Exceptions are Binghamton and State College in electrical engineering; Birmingham in medicine and material sciences; Charleston, Decatur, Greenville-Spartanburg, and Erie in chemicals; Pittsburgh in materials sciences and mathematics; and Huntsville in information technology, electrical engineering, aerospace, and industrial engineering.

There are much more substantial concentrations of scientists and engineers in metro areas along the border of the region, primarily in the areas of chemicals, materials, and industrial engineering. The legacy of chemicals production in and around the region is especially pronounced in the north, with

19. A blank cell in Table 6 or Appendix Tables 7 or 8 indicates that OES data were not available due to few employees in the occupational category, confidentiality restrictions, or inadequate sample size.

Table 6

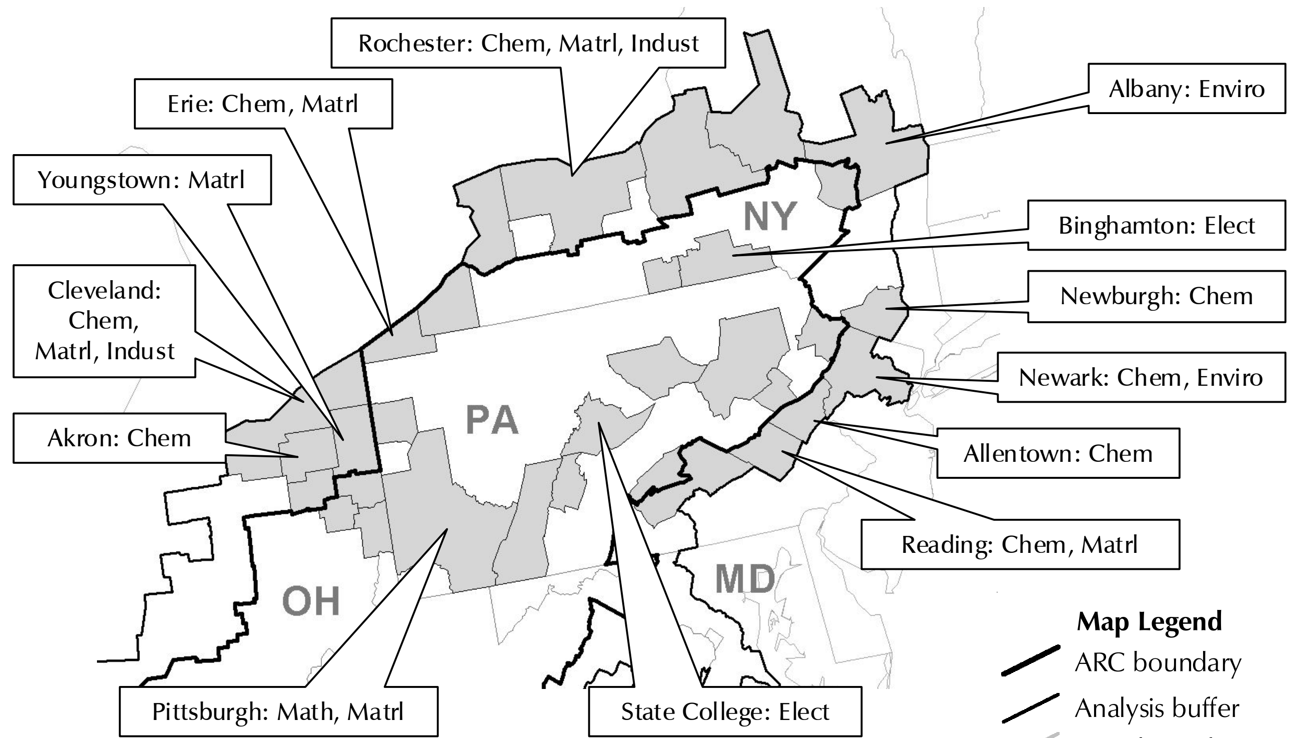
Location quotients: Scientists, engineers and technicians, 1999

ID		MSA	IT	Math	AgSci	Bio	Chem	Enviro	Med	Elect	Matrl	Aero	Geo	Nucl	Indust
4	I	Altoona, PA	0.6												0.5
5	I	Anniston, AL								0.4					0.3
6	I	Asheville, NC	0.3					1.0		0.5					0.4
10	I	Binghamton, NY	1.1							1.4					1.1
11	I	Birmingham, AL	1.1	0.3			0.3	0.6	8.1	0.8	1.6		0.2		0.8
14	I	Charleston, WV	0.3				1.3			0.5					
16	I	Chattanooga, TN-GA	0.3				0.3	0.3		0.4					0.7
21	I	Cumberland, MD-WV													
22	I	Decatur, AL	0.1				2.1			0.6					0.8
23	I	Elmira, NY	0.1							0.3					0.9
24	I	Erie, PA	0.3				1.8			0.5	1.8				1.0
25	I	Florence, AL	0.2				1.0			0.6					0.8
26	I	Gadsden, AL	0.1												
28	I	Greenville-Spartanburg-Anderson, SC	0.5	0.3			2.0	0.3		1.0					1.5
29	I	Hagerstown, MD	0.1							0.7					
33	I	Huntington-Ashland, WV-KY-OH	0.2				1.1			0.3					0.1
34	I	Huntsville, AL	1.7				0.6	0.5		3.4		32.8			2.8
35	I	Jamestown, NY	0.1												0.6
36	I	Johnson City-Kingsport-Bristol, TN-VA	0.2					0.5		0.5					0.4
37	I	Johnstown, PA	0.1							0.2					0.2
38	I	Knoxville, TN	0.4				1.0	1.0		0.9			0.4		0.6
47	I	Parkersburg-Marietta, WV-OH	0.0					0.5		0.7					0.8
48	I	Pittsburgh, PA	0.8	1.2	0.4		0.3	0.4		0.8	2.6		0.2		0.9
52	I	Scranton-Wilkes-Barre-Hazleton, PA	0.5				0.4	0.2		0.7					0.5
53	I	Sharon, PA													0.4
54	I	State College, PA	0.2							1.5					0.3
55	I	Steubenville-Weirton, OH-WV	0.1				1.1			0.6					
60	I	Wheeling, WV-OH	0.2												
61	I	Williamsport, PA	0.2							1.1					
2	B	Albany-Schenectady-Troy, NY	0.8					1.3		0.3	0.4		0.3		0.1
3	B	Allentown-Bethlehem-Easton, PA	0.6	0.2			2.4	0.4		0.5	1.0				0.7
7	B	Athens, GA	0.1				0.8			0.6					0.6
8	B	Atlanta, GA	1.7	1.3	0.5	0.7	0.9	1.0	0.6	1.1	0.4	0.7	0.3		0.9
13	B	Canton-Massillon, OH	0.3							0.2					0.9
17	B	Cincinnati, OH-KY-IN	1.0		0.4	0.9	1.2	0.9		0.5	1.0				1.0
27	B	Greensboro-Winston-Salem-High Point, NC	0.8	0.1		0.2	0.9	0.2		1.1	2.8				0.8
31	B	Harrisburg-Lebanon-Carlisle, PA	1.0	0.2	0.7			0.6		0.5	0.4				0.7
32	B	Hickory-Morganton-Lenoir, NC	0.3				0.6	0.6		0.4	0.7				0.6
39	B	Lexington, KY	0.6				0.4	0.4		0.4			0.4		1.0
43	B	Montgomery, AL	0.8	0.5						0.5					0.1
50	B	Roanoke, VA	0.8	0.5			0.9	0.9		0.8					0.8
57	B	Tuscaloosa, AL	0.0												0.2
59	B	Washington, DC-MD-VA-WV	2.4	4.9	1.3	2.7	0.1	1.5	3.2	1.6	0.5	1.5	1.1		0.7
62	B	Youngstown-Warren, OH	0.2				0.2	0.3		0.2	2.8				0.8
1	O	Akron, OH	0.6				1.4	0.1		0.9					1.2
9	O	Auburn-Opelika, AL													
12	O	Buffalo-Niagara Falls, NY	0.5				1.2	0.5		0.5	1.2				1.0
15	O	Charlotte-Gastonia-Rock Hill, NC-SC	1.1	0.5			1.0	0.7	0.4	0.8		0.6		2.8	1.2
18	O	Cleveland-Lorain-Elyria, OH	0.9	0.1			1.4	0.5	0.3	1.1	1.4				1.7
19	O	Columbus, GA-AL	0.3				2.1			0.3					0.2
20	O	Columbus, OH	1.5	0.5			0.9	0.7	0.2	0.6	0.3				0.8
30	O	Hamilton-Middletown, OH	0.4				0.8			0.8					0.4
40	O	Lynchburg, VA	0.4							0.5					
41	O	Mansfield, OH	0.2							0.7					2.0
42	O	Memphis, TN-AR-MS	0.6	0.9		0.3	1.2	0.4	0.4	0.4	0.2		0.3		0.6
44	O	Nashville, TN	0.6		0.6	1.2	0.3	1.4		0.7	0.2	0.2			0.5
45	O	Newark, NJ	1.0				4.9	1.5		0.9	0.5				0.9
46	O	Newburgh, NY-PA	0.4				2.6	0.6		0.4					0.3
49	O	Reading, PA	0.1				1.7	0.8		1.1	1.6				0.9
51	O	Rochester, NY	0.8			0.2	1.4	0.2		0.4	2.0				1.7
56	O	Syracuse, NY	0.8				0.1	0.9		0.8	0.7				1.2
58	O	Utica-Rome, NY	0.3	0.5						0.6					0.3

Source: Occupational Employment Statistics, U.S. Bureau of Labor Statistics. I: MSA entirely contained within the Appalachian region; B: MSA spans Appalachian border; O: MSA completely outside Appalachia, with borders at least 10 miles from region boundary. N/A: Missing. Blank: No estimate available (see text for explanation). Values > 1.2 are shaded.

Figure 17

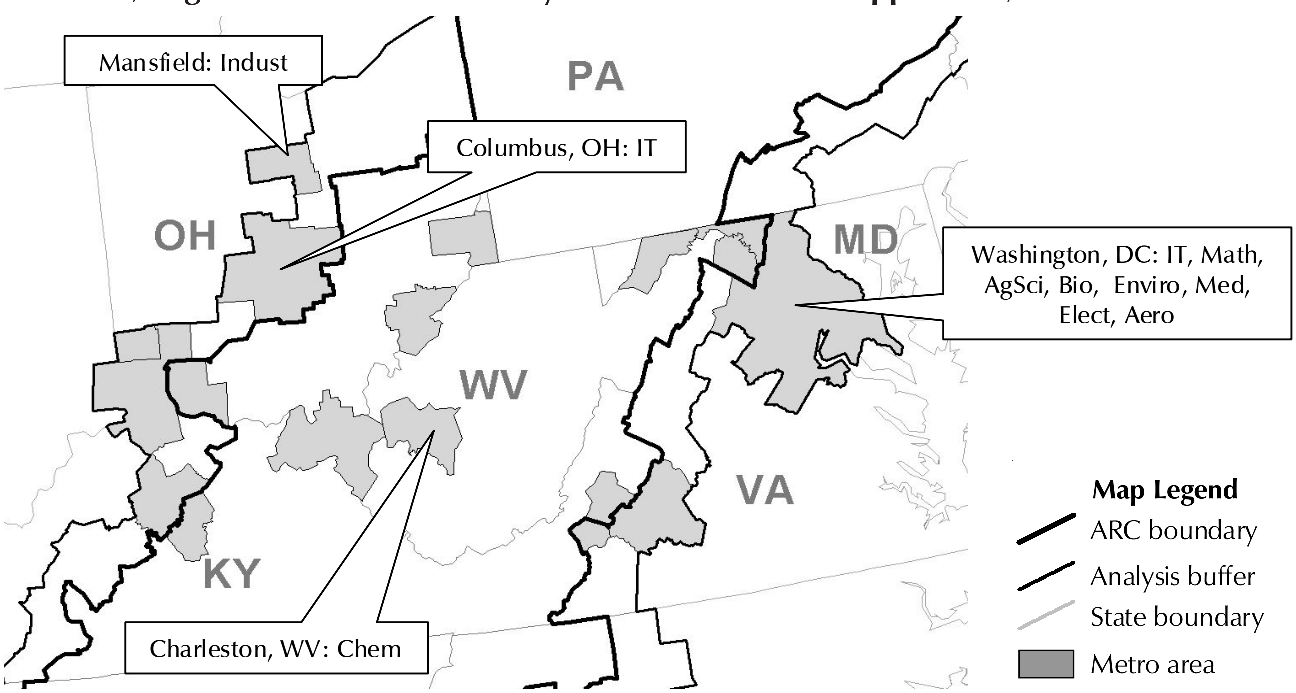
Scientists, engineers and technicians by metro area: Northern Appalachia, 1999



Metro areas with employment location quotients > 1.25 in given technology area indicated. Source: BLS Occupational Employment Survey, 1999. See Table 5 for abbreviated codes.

Figure 18

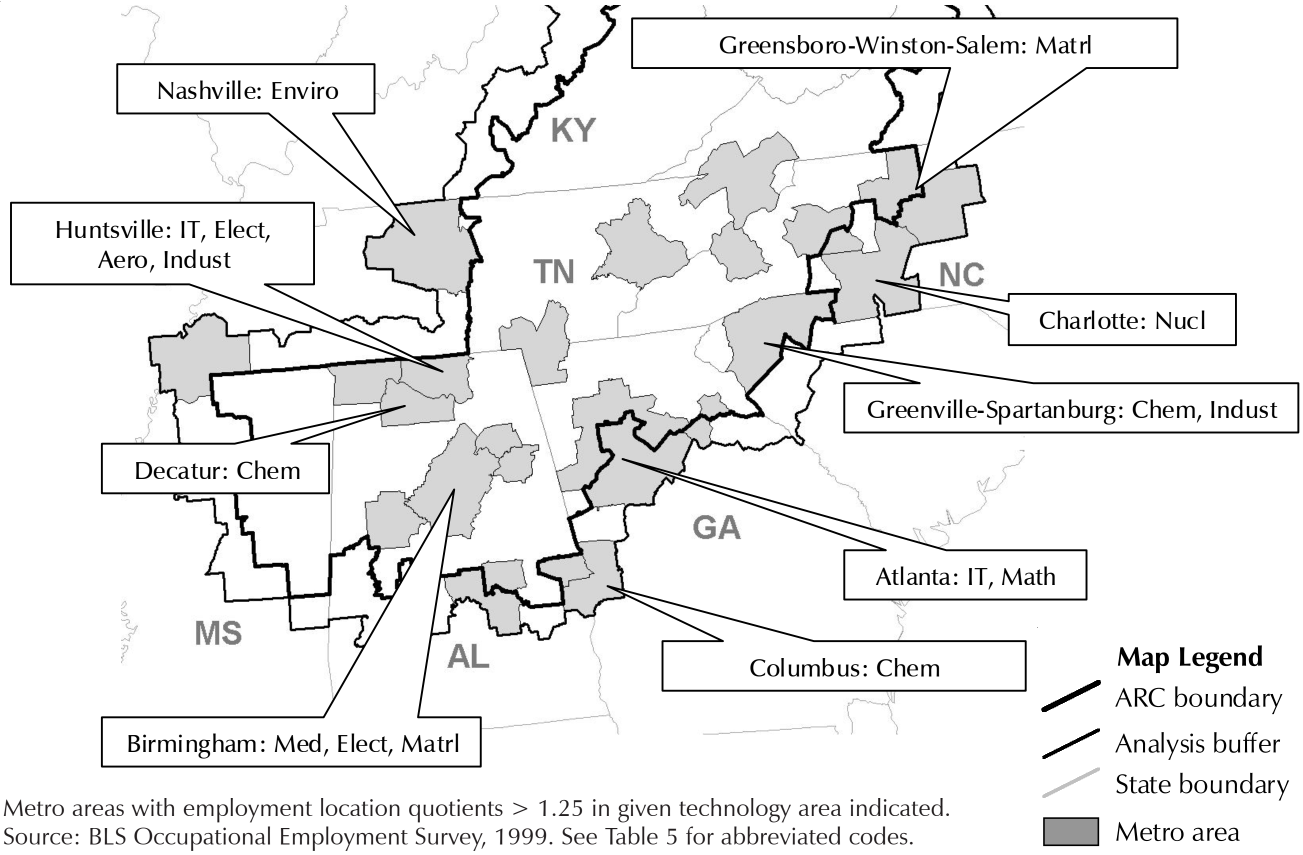
Scientists, engineers and technicians by metro area: Central Appalachia, 1999



Metro areas with employment location quotients > 1.25 in given technology area indicated. Source: BLS Occupational Employment Survey, 1999. See Table 5 for abbreviated codes.

Figure 19

Scientists, engineers and technicians by metro area: Southern Appalachia, 1999



Metro areas with employment location quotients > 1.25 in given technology area indicated.
Source: BLS Occupational Employment Survey, 1999. See Table 5 for abbreviated codes.

above average shares of chemists and chemicals engineers in several MSAs in eastern Pennsylvania and northern Ohio. By the location quotient measure, Columbus, Atlanta, and Washington are specialized in IT-related science and engineering.

2.4 Summary

We have sought to characterize the high-tech industrial base of Appalachia using two basic indicators (industry employment and occupational employment) and three related sectoral classification schemes (technology-intensity, value-chain linkages, and occupational category). While the concordances are imperfect, it is possible to map the occupational categories to the eight value-chain categories to permit a focus on a manageable set of technology areas or sectors. Overlaying the employment and occupation data then generates a rich picture of technology-intensive industrial specializations and strengths within and nearby the ARC region. We present those detailed overlay maps in Section 4, along with additional data layers representing various dimensions of Appalachia's knowledge infrastructure (the subject of the analysis in Section 3).[20] Focusing just on the results to this point, however, we can identify the following major findings:

- Overall, Appalachia's greatest strengths appear to be in sectors of moderate technology-intensity. Sectors classified as moderately technology-intensive are well represented in the region and grew at rates well above the national trend during the 1990s. Industries of very high technology-intensity are comparatively few in the region, while sectors on the low-end of the technology spectrum are not expanding.
- The same story is reflected in the mix of high tech-value chains in the region, where the principal strengths are in the areas of chemicals/plastics and industrial machinery. Chemicals/plastics and industrial machinery account for most of the spatial concentrations of technology-related employment found in or immediately adjacent to the ARC region.
- In terms of a diversity of technology-related industry, there are five leading metropolitan areas in Appalachia: Binghamton, Greenville-Spartanburg, Huntsville, Johnson City, and Pittsburgh. We found evidence of high-tech concentrations in four or more value-chains in at least parts of each of those cities (seven and six in the cases of Huntsville and Greenville-Spartanburg, respectively). A second group of cities that are also home to multiple value-chain concentrations include Asheville, Decatur, Erie, Knoxville, and State College, PA.
- The industrial machinery, chemicals/plastics, and motor vehicles concentrations tend to be larger in spatial extent (comprised of larger multi-county areas) than the other technology areas. That is, their presence (or sometimes extension into) rural counties is more extensive than sectors such as information technology, communication services, and software.
- Within the ARC region proper, there is clearly an orientation of high-tech activity to the northern and southern thirds of the region, with activity in the central region very sparse in several key technology areas. Chemicals and plastics industries exhibit the strongest presence in the central third of the ARC area, whether measured by value chain employment or occupational employment.
- Appalachian metro areas have a significantly lower complement of scientists, engineers, and related technicians than the U.S. as a whole. Scientists and engineers are somewhat better represented in the MSAs that line the region's borders. Washington, DC accounts for a significant share of the total scientists and engineers employed in the 62 metro areas included in the study. Excluding the Washington, DC MSA finds the southern third of the extended region the most "science and engineering-intensive" based on occupational employment indicators.

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20. Throughout the report, we often label concentrations of activity according to the nearest major city. However, because many concentrations encompass several cities and even adjoining rural areas, the labels themselves should be viewed as indicating only the general vicinity of the given cluster.

3 Appalachia's Knowledge Infrastructure

Appalachia's knowledge infrastructure is 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.[21] (In the case of major research universities, the two components come together.) Appalachia's science and innovation assets are based in eighteen research universities and a limited number of other research institutions (such as federal government laboratories), non-profit R&D organizations, state-sponsored technology agencies, and private sector businesses engaged in innovation. The R&D activities within universities span almost all academic disciplines in the sciences, applied sciences, and engineering, and also describe a large variety of technology-related specialties within non-university institutions. Although the research universities and other R&D institutions are located in twelve states in the ARC region, the most competitive disciplines and technology areas are concentrated in a fairly small number of nodes.

Appalachia'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 1997/98, four-year institutions conferred over 23,600 science and engineering degrees while two-year colleges and institutes granted an additional 12,200 degrees. Available programs and training are extensive in some technology areas (e.g., communications and computer sciences, aerospace engineering and aviation sciences, industrial engineering, agricultural sciences, and basic medical sciences) but comparatively sparse in others (e.g., biochemistry and biomedical engineering at the two-year level). An analysis of the mix of programs relative to U.S. averages provides an excellent picture of the education and training orientation of Appalachia's teaching colleges and universities in technology-related fields.

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21. A strong case could also be made for including primary education as a component of knowledge infrastructure. Indeed, the foundation for lifelong learning necessary to sustain a knowledge-intensive economy is laid in the primary and secondary schools. However, since this report's aim is to identify specific technology-oriented strengths, it focuses exclusively on institutions of higher education.

3.1 Appalachia's Science and Innovation Assets

The science and innovation component of Appalachia's knowledge infrastructure consists of performers of R&D (universities, labs, and private firms) and a support system of state-funded technology agencies and programs. The latter generally do not conduct R&D, but rather seek to diffuse best practice technologies through the provision of a variety of subsidized industrial extension services. The following sub-sections explore the innovation assets of the region using the set of complementary indicators summarized in Table 7.

3.1.1 R&D Performers

The major categories of R&D performer in Appalachia are research universities, non-university R&D organizations (including federal government labs), and private sector firms. The comparative strength of the universities is easiest to evaluate since data on faculty quality, R&D funding, enrollments, patents, and gross license income are available. The lack of reliable performance data for non-university laboratories and private sector R&D performers (i.e., private businesses) precludes systematic comparative evaluation of those sectors. However, proxy indicators (budget figures for federal labs and patents and federal grants participation for businesses) can provide at least limited information on the level and location of science and innovation activity in those sectors. Moreover, in the case of private business, science and innovation activity is partly indicated by the size, mix, and spatial distribution of technology-intensive industries analyzed in Section 2.

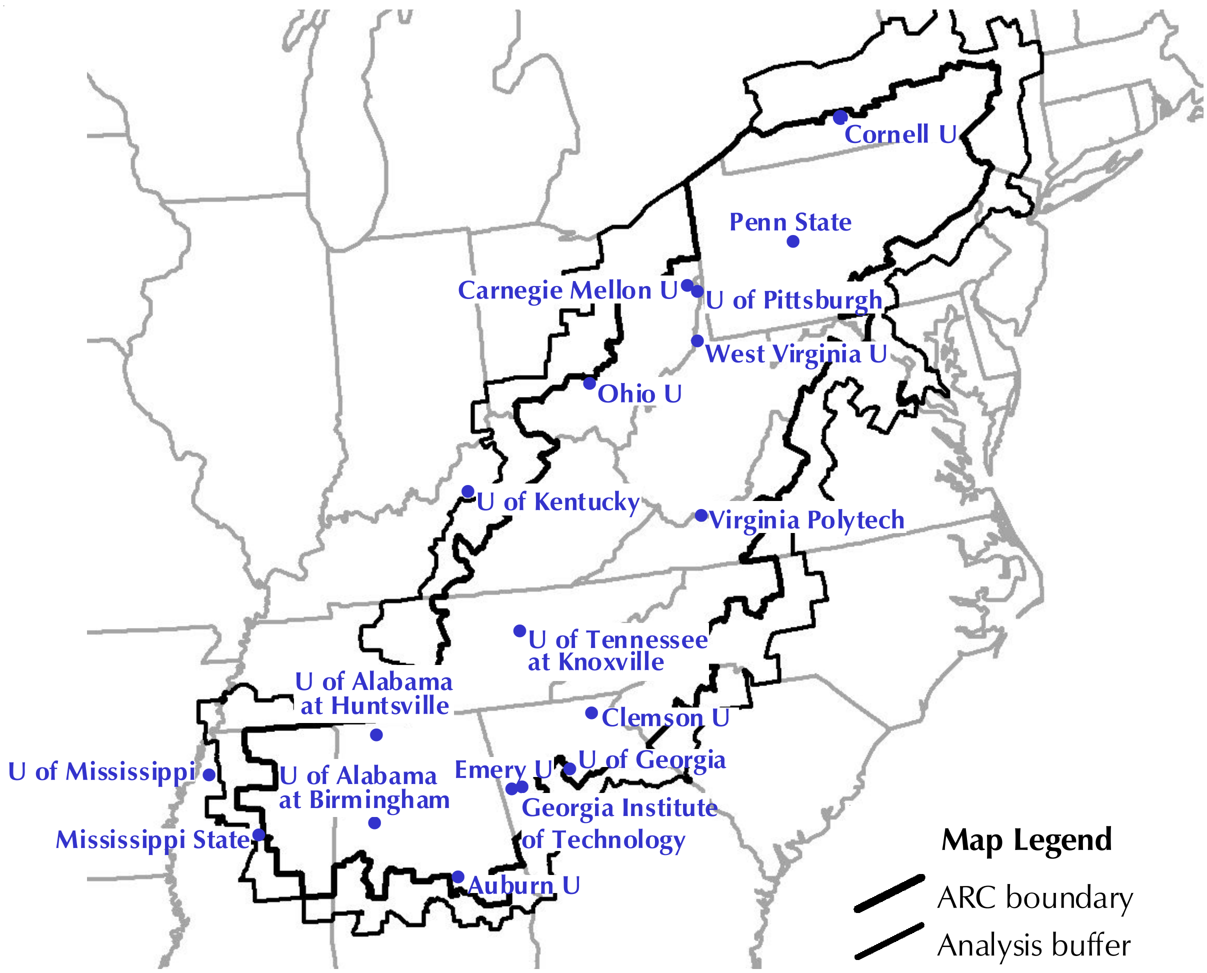
Research Universities. There are eleven research universities located in the 406-county ARC region: Carnegie-Mellon, Clemson, Cornell, Mississippi State, Ohio University (consolidated, but domi-

Table 7
Study measurement of innovative activity

Rating of faculty quality, research universities, by academic discipline	1995	National Research Council
Research expenditures (all sources), research universities by academic discipline	1991, 1999	NSF CASPAR database
Enrolled graduate students, research universities, by academic discipline	1991, 1999	NSF CASPAR database
Patents issued, research universities (all disciplines)	1999	AUTM Survey
Gross license income, research universities (all	1999	AUTM Survey
Non-university research organizations receiving federal funds in the ARC region, by location and technology area	1999, 2000	NSF, various
Utility patent grants by county, measured as location quotients and G statistics	1990-1999	US Patent and Trademark Office
SBIR, STTR, and ATP award winners in ARC region, FY 2000, by location and technology area	2000	Federal government agency databases

nated by Ohio State), Penn State, the University of Alabama at Birmingham, the University of Pittsburgh, the University of Tennessee, Virginia Tech, and West Virginia University. There are an additional six research universities situated adjacent to or very nearby the ARC boundary: Auburn University, Georgia Tech, Emory University, the University of Georgia, and the University of Mississippi. We included the six adjacent schools in the analysis on the assumption that their close spatial proximity yields a high potential spillover effect into the ARC region. We also added one additional institution not classified as a doctoral university (extensive) by the Carnegie Foundation — the University of Alabama at Huntsville — because of its strong technology focus.[22] The locations of the eighteen research universities in the study are plotted in Figure 20.

Figure 20
Major research universities within and adjacent to ARC boundary



22. We assembled our list of doctoral-research universities inside and nearby the ARC region from the Carnegie Foundation's recently revised classification of institutions of higher education (McCormick 2001). The newly revised classification system includes two categories of doctoral-research universities. Doctoral research

footnote continues next page

We developed three measures of 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. Two additional measures of competitiveness — the number of patents issued to universities and gross license income in 1991, 1995, and 1999 — could not be disaggregated by discipline.[23] To establish a common scale for combining the disparate dimensions of research strength, we converted the measures of perceived faculty quality, research funding, and enrollment into national rankings.[24]

Based on ratings of faculty quality, there are six major nodes of highest competitive strength in Appalachia: Cornell (Ithaca, NY), Carnegie-Mellon (Pittsburgh, PA), Georgia Tech (Atlanta, GA), Emory University (Decatur, GA), Penn State (State College, PA), and Virginia Tech (Blacksburg, VA). Each of those universities ranks among the top-twenty universities in the U.S. in at least one science or engineering discipline and among the top-forty universities nationally in at least three other disciplines. Eight additional universities rank in the U.S. top forty in at least one discipline: University of Alabama at Birmingham, University of Alabama at Huntsville, Auburn, Clemson, University of Georgia, University of Kentucky, University of Pittsburgh, and the University of Tennessee.

By discipline, the faculty quality rankings indicate that the greatest competitive strengths among Appalachian research universities as a group are oriented toward the physical sciences and engineering rather than the biological and medical sciences (see Table 8). Overall, the disciplines of greatest strength are mechanical engineering, civil engineering, electrical engineering, industrial engineering, materials science, chemistry, statistics, and computer science. Among the biomedical disciplines, only five de-

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universities (extensive) are institutions that grant fifty or more doctoral degrees per year across at least fifteen disciplines; doctoral research universities (intensive) are institutions that grant ten or more doctoral degrees per year across three or more disciplines, or at least twenty doctorates per year overall. All of the universities included in this study but the University of Alabama-Huntsville are doctoral-research universities (extensive). We added the University of Alabama at Huntsville to the group of universities in the study because of National Science Foundation data indicating comparatively high rankings on research funding in several engineering and scientific disciplines.

23. The faculty quality ratings are from the National Research Council's 1995 *National Survey of Graduate Faculty* (Goldberger, Maher *et al.* 1995). The survey asks peer faculty to rate doctoral programs within their respective disciplines on a scale of zero (lowest) to five (highest). The ranks are based on mean scores for each university. Research expenditures (external funding) and the number of full-time graduate students enrolled by academic discipline are from the National Science Foundation's Internet-based *webCASPAR* database (http://caspar.nsf.gov). Data on the number of patents issued to universities and gross license income are from the Association of University Technology Managers (AUTM 1991, 1995, 1999).

24. In the case of faculty quality, patents, and license income, the classification of disciplines is from the National Research Council. The discipline classification for research funding and enrollments is from the National Science Foundation. While there is a close match between the NRC and NSF categories in engineering and the physical sciences, the NSF classification is more aggregated in the biological sciences than the NRC scheme.

Table 8
Rankings of faculty quality: Appalachin research universities, 1995

Discipline	UA at Birmingham	UA at Hunstville	Auburn	Carnegie Mellon	Clemson	Cornell	Emory	Georgia Tech	U of Georgia	U of Kentucky	Mississippi State U	U of Mississippi	Ohio U	Penn State U	U of Pittsburgh	U of Tennessee at Knoxville	Virginia Tech	West Virginia U	Average*
Aerospace Engineering			32			6		9						17		31	15		18
Biomedical Engineering	25				33									19					26
Civil Engineering			54	12	62	6		17		53		86		32	50	65	19	66	44
Chemical Engineering			71	12	81	13		30		71		93	92	23	44	59	42	68	54
Electrical Engineering		95	59	12	73	7		13		97	102		85	28	63	66	27	88	58
Industrial Engineering		35	20		31			1						9	23		8		18
Materials Science	55	61	64	11		3		44		62				9	45		38		39
Mechanical Engineering		94	75	19	63	7		18		71				17	69	77	29	85	52
Astronomy						9								21					15
Chemistry	126		123	74	94	6	38	64	49	99	159	157	147	18	34	78	67	130	86
Computer Sciences	97	87		4		5		32		65	99			54	43		66		55
Physics	127	114	128	28		6		61	75	91		141	83	55	40	72	71		78
Ecology	119				80	4			16	72	112		107	26	92	40	70		67
Geo-Sciences						9		76	76	83				12	75	61	27	98	57
Math		130	93	40	92	15		44	58	71		136	124	37	61	77	66		75
Statistics	62			16		4	51			49				19	37		41		35
Biochemistry	49				175	22	76	112	66	93			185	45	89	165	130	128	103
Cellular Development	48		157		126	35	52	178	132	76			144	56	69	78		115	97
Molecular Genetics	45				91	23	32	90	40				100	32	46	95		81	61
Neurosciences						24	33						85	67	40				50
Pharmacology	77				110	65	15		88	31		107	125	75	44			50	72
Physiology	20		105		112	31	22		85	72			119	37	47		2	85	61
Average*	71	88	82	23	87	15	40	53	69	72	118	120	116	32	53	74	45	90	56

Source: National Research Council. Averages are only calculated on ranked values; missing values are not included.
Dark shading = Top 20; light shading = Top 40.

partments are among the top twenty nationally: Cornell and University of Georgia in ecology, Emory in pharmacology, and Virginia Tech and the University of Alabama at Birmingham in physiology. Physiology was the strongest biomedical discipline overall, with three universities boasting top-forty departments (Cornell, Emory, and Penn State).

A more objective indicator than faculty quality rankings is the national ranking of a university by its total garnered R&D funding, by discipline. An institution's R&D rank is an excellent quantity indicator of its relative contribution to the generation of new knowledge. The analysis of the rankings of the universities in the ARC region in 1999 reveals a surprising number of competitive strengths spread over a diverse number of disciplines and spatial nodes. Indeed, the pattern of R&D spending suggests that Appalachian universities are stronger in the life sciences disciplines than suggested by the faculty quality rankings.

Of the fifteen disciplines in the natural sciences and engineering for which data are available, there are eleven in which there is at least one Appalachian (or nearby) university with a top-ten ranking (see Table 9). In two of those disciplines (computer science and agricultural sciences), there are three universities with top-ten departments, and in five other disciplines (aerospace engineering, electrical engineering, mechanical engineering, materials engineering, and chemistry), there are two universities

Table 9

Rankings of R&D funding: Appalachin research universities, 1999
Research expenditures by academic discipline

Discipline	Auburn U, All Campuses	Carnegie Mellon U	Clemson U	Cornell U, All Campuses	Emory U	GA Tech, All Campuses	Mississippi State U	Ohio U, All Campuses	Penn State U, All Campuses	U of Alabama at Birmingham	U of Alabama at Huntsville	U of Georgia	U of Kentucky, All Campuses	U of Mississippi, All Campuses	U of Pittsburgh, All Campuses	U of Tennessee Univ-Wide	Virginia Tech	West Virginia U
ENGINEERING	56	29	37	17		2	36	85	4	93	60	94	43	109	89	42	16	55
Aerospace Engineering	32			12		4	30	16	22							9	18	
Chemical Engineering	28	30	77	42		13	61	67	22		47		55	99	35	36	39	73
Civil Engineering	61	55	32	37		7	73	69	13	97	89		100	99	98	20	12	30
Electrical Engineering	70	23	37	16		1	59	97	5	110	47		91	108	100	60	17	80
Mechanical Engineering	55	33	36	78		4	68	95	7		25		63	102	98		14	21
Materials Engineering	49	20		26		10		69	1	22	59			55	46	44	30	68
PHYSICAL SCIENCES	113	71	87	6	86	35	116	106	15	111	70	66	89	101	60	54	75	103
Astronomy	39			5				42	20						36			
Chemistry	118	80	79	8	57	29	95	120	7	110	105	51	86	123	49	70	52	106
Physics	103	51	77	6	112	25	119	73	14	99	41	70	74	69	71	35	100	82
GEOSCIENCES	104	83	92	65		30	74	101	13	120	61	33	99		105	39	18	73
MATH AND COMPUTER SCIENCES	110	3	68	11	100	7	76	125	53	111	40	39	84	124	57	38	52	113
Mathematics and Statistics	96	20	39	28	75	19	86	120	23	97	50	13	77	124	66	83	34	117
Computer Science	114	3	73	10	110	7	66	118	76	113	29	54	77	116	50	23	61	101
LIFE SCIENCES	80	111	79	13	22	107	72	120	50	17	128	26	38	115	18	59	68	92
Agricultural Sciences	24		32	15		51	8		33			3	12			27	5	45
Biological Sciences	85	106	59	29	40	110	122	102	22	16	126	15	115	125	96	64	89	88
Medical Sciences	94		98	17	21	76	83		63	13		64	38	81	7	51	89	69
S&E TOTAL	92	64	84	12	44	29	79	126	14	36	113	34	48	127	33	54	49	102

Source: National Science Foundation WebCASPAR Database System. Dark shading = Top 20; light shading = Top 40. National rankings for Research I & II universities (131 universities ranked). R&D data for the industrial engineering discipline were are not reported by NSF, though graduate enrollment data are reported

with top-ten departments. All fifteen disciplines have at least one university in or near Appalachia with a top-twenty ranking. Leading universities in the biological or medical life sciences include Cornell, the University of Alabama at Birmingham, the University of Georgia, the University of Pittsburgh, and Emory University.

The distribution of strengths among the universities is also noteworthy. Of the eighteen research universities within the ARC region, nine boast at least one top-ten department, and twelve have at least one top-twenty department. The leading schools are Georgia Tech, Cornell, Penn State, and Virginia Tech in terms of the number of highly ranked disciplines, but there are competitive strengths spread out among almost all of the other universities. Moreover, there are a number of programs whose funding rank improved substantially between 1991 and 1999, even if the rank in 1999 was still below the top-ten or twenty. Table 10 identifies 34 such programs in total. Among the leaders with at least three emergent disciplines apiece (based on funding rank) are Carnegie-Mellon, Georgia Tech, Ohio, Penn State, University of Kentucky, Virginia Tech, West Virginia University, and Mississippi State. Emory University and University of Alabama at Birmingham each boast two emergent disciplines.

Similar to R&D expenditures, the number of graduate students enrolled by academic discipline is a quantity indicator of a university's academic strength in a given field. Enrollments indicate universities' potential contribution of highly skilled human capital. Table 11 reports 1999 national graduate student enrollment rankings by discipline for the eighteen universities in or adjacent to the ARC region. There is an impressive distribution of strengths across a wide variety of disciplines and universities. Fourteen of the sixteen disciplinary areas are represented by top-ten university departments, and all sixteen have top-twenty representatives. Specifically, there are three top-ten university programs in industrial engineering in or adjacent to the region (Georgia Tech, Virginia Tech, and the University of Alabama at Huntsville), and two top-ten programs in civil engineering (Georgia Tech and Virginia Tech), materials engineering (Georgia Tech and Penn State), and computer science (Carnegie-Mellon and the University of Pittsburgh).

Table 10

Emergent strengths in Appalachian universities, 1991–1999
Ranking shifts based on R&D expenditures and enrollments, 1991–1999

Aerospace Engineering	Ohio University[a], West Virginia[b]
Chemical Engineering	Carnegie-Mellon[a], Georgia Tech[c], Penn State[a], University of Alabama-Huntsville[a], University of Kentucky[a]
Civil Engineering	Virginia Tech[c], West Virginia[c]
Electrical Engineering	Penn State[c], Virginia Tech[b]
Mechanical Engineering	Carnegie-Mellon[a], Mississippi State[a], West Virginia[a]
Materials Engineering	Carnegie-Mellon[a], Ohio University[a], University of Alabama-Birmingham[a], Penn State[b]
Astronomy	Auburn[a], Ohio University[a]
Chemistry	None
Physics	Georgia Tech[a], Penn State[c], University of Kentucky[a], West Virginia[a]
Geosciences	Georgia Tech[a], Virginia Tech[a], University of Georgia[b], University of Alabama-Huntsville[b]
Mathematics and Statistics	Carnegie-Mellon[a], Emory[a], Mississippi State[a], University of Georgia[c], Cornell[b], Georgia Tech[b], University of Kentucky[b]
Computer Science	Mississippi State[a], University of Alabama-Huntsville[a], University of Kentucky[a], University of Pittsburgh[a], Carnegie-Mellon[b], Virginia Tech[b], West Virginia[b]
Agricultural Sciences	Virginia Tech[a]
Biological Sciences	Emory[a], University of Alabama-Birmingham[b], Pittsburgh[b]
Medical Sciences	Georgia Tech[a], Emory[b]

Source: National Science Foundation and authors' calculations. [a]Substantial shift in national R&D funding rank between 1991 and 1999. [b]Substantial shift in graduate student enrollment rank between 1991 and 1999. [c]Substantial shift in both R&D funding and graduate student enrollment rank between 1991 and 1999.

Table 11

Graduate student enrollment rankings: Appalachian research universities, 1999

	Auburn U, All Campuses	Carnegie Mellon U	Clemson U	Cornell U, All Campuses	Emory U	Georgia Tech, All Campuses	Mississippi State U	Ohio U, All Campuses	Penn State, All Campuses	U of Alabama at Birmingham	U of Alabama at Huntsville	U of Georgia	U of Kentucky, All Campuses	U of Mississippi, All Campuses	U of Pittsburgh, All Campuses	U of Tennessee Univ-Wide	Virginia Tech	West Virginia U
ENGINEERING	67	40	44	30		1	73	87	14	99	100	116	71	104	39	38	8	46
Aerospace Engineering	25			31		1	30		20							29	11	35
Chemical Engineering	47	13	69	24		9	63	70	22		90		75	91	23	38	59	66
Civil Engineering	62	57	22	20		3	97	90	26	87	98		51	88	49	36	10	39
Electrical Engineering	95	30	51	34		3	44	64	26	105	54		70	101	37	81	11	69
Mechanical Engineering	61	42	30	31		3	91	54	11	99	55		82	100	53	43	21	34
Materials Engineering	28	25	29	17		7			6	45	51		56		36	46	35	
Industrial Engineering	41		39			1	56	54	21		6		63		28	19	3	36
PHYSICAL SCIENCES	102	92	55	17	87	38	117	91	4	120	106	59	66	119	34	52	73	97
Astronomy				17					23									
Chemistry	89	101	71	34	51	31	108	91	9	122	124	42	70	120	26	64	52	96
Physics	104	69	84	11	117	47	120	67	3	103	52	96	53	105	42	35	98	90
GEOSCIENCES	98		97	34		58	67	53	7		68	46	77	94	88	66	54	79
MATH AND COMPUTER SCIENCES	71	11	56	26	118	23	82	101	36	105	72	52	58	104	10	42	16	51
Mathematics and Statistics	71	48	67	4	98	51	97	49	23	119	103	43	28	122	34	37	30	56
Computer Science	67	6	50	45		16	66		41	93	54	56	84	83	8	43	14	48
LIFE SCIENCES	80	126	82	29	14	125	91	116	38	9	110	35	34	96	19	36	70	53
Agricultural Sciences	21		24	17			15		28			19	30			41	13	32
Biological Sciences	99	126	85	7	59	124	101	118	16	15	125	14	44	97	46	53	82	100
Medical Sciences	62			65	2		79		68	13		56	44	74	29	17	64	66
S&E TOTAL	85	60	78	25	67	21	101	110	17	58	111	64	50	118	26	46	32	61

SOURCE: NSF WebCASPAR Database System. Dark shading = Top 20; light shading = Top 40. National rankings for research I and II universities (131 universities ranked).

The principal spatial nodes of strength based on graduate student enrollments are similar to those for R&D funding. Georgia Tech, Penn State, Cornell, and Virginia Tech are the leading locations. Yet eight universities boast at least one top-ten program, and thirteen have at least one top-twenty department. There are also twenty university programs that can be classified as emergent based on improvements in their national enrollment rankings between 1991 and 1999 (see Table 10). They are distributed among twelve of the disciplines. There are three emergent programs apiece at Penn State, Virginia Tech, and West Virginia; two apiece at Georgia Tech and University of Georgia; and one apiece at Emory, Carnegie-Mellon, University of Alabama at Huntsville, University of Kentucky, Alabama-Birmingham, University of Pittsburgh, and Cornell.

Two final indicators of university strength are the number of patents issued and total gross license income (see Table 12). Both are measures of innovative activity that has the potential for application in the marketplace. According to data collected by the Association of University Technology Managers (AUTM), twelve research universities in or nearby the ARC region generated at least ten patents in 1999.[25]

25. Note that the AUTM data are reported only for university-wide systems in the case of Ohio University, the University of Tennessee, and the University of Pittsburgh.

The leading schools were Cornell (70 patents), Penn State (46 patents), Emory (44 patents), Virginia Tech (37 patents), and Carnegie-Mellon (30 patents). Appalachian and nearby universities garnered roughly $48.6 million in gross license income in 1999, with Emory University accounting for one-third of the total. Ten schools generated gross license income of at least $1 million in 1999.

Table 12
Patents issued and gross license income, 1999
(Sorted by gross license income)

Institution	Patents Issued	Gross License Income
Emory University	44	16,166,848
Cornell University	70	6,400,000
Carnegie Mellon University	30	5,892,284
Clemson University	2	4,648,141
University of Georgia	21	3,208,427
Pennsylvania State University	46	2,830,448
University of Kentucky	24	2,496,786
Georgia Institute of Technology	23	2,038,078
University of Alabama at Birmingham	24	1,562,778
Virginia Polytechnic Institute	37	1,328,343
*Ohio University	4	635,611
*University of Tennessee	17	620,903
*University of Pittsburgh	30	608,851
Auburn University	12	186,738
West Virginia University	2	41,800
Mississippi State University	NI	NI
University of Mississippi	NI	NI

Source: Association of University Technology Managers *Licensing Survey*, Fiscal Year 1999, Table 8. *Data available only for all campuses. NI: Institution was not included in the AUTM survey.

Federally Funded Non-University Research Organizations. The second major category of R&D performer in the Appalachian region is the non-university-based organization that receives federal research funds. We used National Science Foundation data on federal funds provided to non-university R&D performers, federal agency web sites, and information from state development officials and other individuals familiar with the science and technology base of each state to identify eighteen qualifying facilities located in six Appalachian states (see Table 13). We were able to document research-funding levels only for defense-related labs.[26]

There are several significant federal government research complexes in the ARC region. They are clustered in two principal locations: Huntsville, Alabama (aerospace and related activities) and Oak Ridge, Tennessee (energy-related research). Both are places without major research universities and outside the cores of large metropolitan areas. Another smaller complex is the NASA facility at Green Bank, West Virginia (astronomy research). There are additional, less-well-known federal government research operations in Pittsburgh (the NSF Data Storage Center), in Watervliet, New York (Army Benét Laboratories), and at Arnold Air Force Base, Tennessee (the Engineering Development Center). Several state government and non-profit research organizations, but which are primarily funded through the National Science Foundation, also operate in the ARC region.

Private Sector R&D. A third and extremely important element of Appalachia's science and innovation base are the many private sector businesses actively engaged in research, applied innovation,

26. The funding data are from Department of Defense budget documents.

Table 13
Appalachian non-university research organizations

Name	City/Town	State	Technology	Funding 1997	Source
Southern Research Institute	Birmingham	AL	Other		
Army Space and Missile Defense Command	Huntsville	AL	Aerospace		
Marshall Space Flight Center	Huntsville	AL	Aerospace		
Army Aviation and Missile Command RD&E	Redstone Arsenal	AL	Aerospace		
Army Redstone Technical Test Center	Redstone Arsenal	AL	Aerospace		
Army Missile Research Dev and Engineering Ctr	Redstone Arsenal	AL	Aerospace		
Army Benet Laboratories	Watervliet	NY	Aerospace	$697,986,000	3
NSF Data Storage Center	Pittsburgh	PA	Comm services & software		
Software Engineering Institute	Pittsburgh	PA	Comm services & software		
SC Research Institute		SC	Other		
Air Force Arnold Engineering Development Ctr	Arnold AFB	TN	Aerospace		
Oak Ridge Institute for Science and Education	Oak Ridge	TN	Other		
Oak Ridge National Laboratory	Oak Ridge	TN	Industrial machinery	$233,785,000	1
National Radio Astronomy Observatory	Green Bank	WV	Aerospace	$532,000	2
National Energy Technology Laboratory	Morgantown	WV	Industrial machinery	$16,395,000	1
NASA Independent Validation and Verification Facility	Fairmont	WV	Comm services & software	$21,659,000	2
WV High Tech Consortium	Fairmont	WV	Other	$202,000	2
WV Research Corp		WV	Other	$5,540,000	2

1: NSF, Federal Funds for Research and Development: Fiscal Years 1997, 1998 and 1999, NSF 99-333.
2: NSF, Federal Science and Engineering Support to Universities, Colleges and Nonprofit Institutions, Fiscal Year 1998, NSF-00-315.
3: NSF, State Science and Engineering Profiles and R&D Patterns: 1997-98, NSF 00-329

and development. Unfortunately, data on private sector R&D activity are very limited. Even the National Science Foundation's industry surveys are based on very small samples and cannot be disaggregated to the sub-state level.[27] While counts of both patents and federal innovation grants (under the Small Business Innovation Research program, Small Business Technology Transfer Research program, and Advanced Technology Program) cannot be regarded as direct proxies of private sector R&D generally, they can provide a partial picture of the geographical distribution of private sector science and innovation in the region.

Utility Patents. A patent is an attempt by an inventor to appropriate fully and exclusively any returns derived from her innovation, at least for a limited period. Utility patent grants by sector are thus a partial indicator of applied innovative activity.[28] While some patents are granted to universities and non-profit R&D performers, the vast majority are secured by private industry.

We use 1990 to 1999 county-level utility patent data provided by the U.S. Patent and Trademark Office (USPTO) to calculate *G* statistics and location quotients for the extended Appalachian study

27. One NSF official also noted that even the state-level industrial R&D estimates published by his agency are suspect, given very small samples and a strong bias toward large companies.

28. The difficulties of working with patent data and some of the caveats that must be considered in their use are discussed in Griliches (1990) and Feser, Goldstein *et al.* (1998).

region. The USPTO assigns patents to counties based upon residence of the inventor.[29] Utility patents are initially classified by invention or product, which the USPTO then re-classifies into industries using the 1972 SIC definitions. Using the USPTO SICs, we organized patents into ten technology sectors that roughly correspond to the high-tech value-chains (see Table 14). Appendix Table 9 lists the USPTO SIC components of each aggregated sector. The USPTO commonly assigns a single patent to multiple SICs and therefore a patent may be included in more than one technology sector. Figures 21–30 display the mapped overlays of the concentration indicators.[30]

Table 14
Utility patent grants over period, 1990–1999, U.S. & ARC region

	U.S.		13 ARC states			ARC counties		
Technology area	Total	Pct share	Total	Pct share	LQ	Total	Pct share	LQ
Chemicals and plastics	224,930	20.3	33,404	24.5	0.97	5,848	23.8	1.17
Information technology	363,069	32.8	34,617	25.4	0.93	5,767	23.5	0.72
Instruments	180,424	16.3	23,844	17.5	0.73	3,134	12.8	0.78
Industrial machinery	230,781	20.8	26,132	19.2	1.28	6,015	24.5	1.18
Motor vehicles	153,722	13.9	16,466	12.1	1.17	3,462	14.1	1.02
Aerospace	54,160	4.9	5,099	3.7	1.26	1,153	4.7	0.96
Household appliances	14,136	1.3	2,027	1.5	1.09	396	1.6	1.26
Pharmaceuticals	65,733	5.9	10,896	8.0	0.45	889	3.6	0.61
Metals	116,818	10.5	16,263	11.9	1.21	3,556	14.5	1.37
Other	72,272	6.5	11,353	8.3	1.21	2,463	10.0	1.54
Total (not sum)	1,108,391		136,425			24,562		

Source: U.S. Patent and Trademark Office (special data request). Categories are not mutually exclusive.

29. At best, this is only a rough approximation of the location of innovation. It assumes that the county of residence is an accurate representation the individual or institution that took a primary role in creating the invention. Many inventions are developed in multiple places while others are developed in one particular place before another person or institution in a different location subsequently patents them. Furthermore, it is unclear whether an inventor's place of work or residence is the more accurate way to identify innovative places. It may make more sense to think of innovative regions rather than try to pinpoint the site of innovation. Under typical metropolitan commuting patterns, residential areas are peripheral to work sites in the urban core. But these patterns are changing and suburb-to-suburb commuting has become the norm in many regions. Furthermore, the conduit for the spread of innovation and ideas is a complex web of economic and social interactions that might be limited by geography, but is not necessarily subject to imaginary boundaries between work and home.

    Note that patents with multiple inventors living in different counties are weighted by the total number of inventors. For example, if a single patent has two inventors that live in different counties, each county is assigned half of the patent. Because the G_i statistic is designed to reveal spatial association among counties, it helps offset the discrepancy caused by differences in inventor residency and work locations.

30. We adopted the slightly stricter standard of 1.25 for highlighting location quotient values in Figures 21–30 since the magnitude of patent grants is much lower than employment. The lower the magnitude of a given variable in the location quotient formula, the greater the variation in the indicator.

Our analysis of the spatial distribution of patenting activity by technology area using the *G* statistic indicates that localized concentrations of patent grants are almost always located in metropolitan areas, regardless of technology sector, a result that supports the conventional wisdom that cities, and the suburbs where their workers live, are the primary hotbeds of applied innovative activity. It is also noteworthy that many of those concentrations are in the same few metropolitan areas even across different technology sectors. Also, much of the localized activity is just outside the ARC boundary, and for the most part, is more likely to be adjacent to northern Appalachia than the central or southern parts of the region. It is important to note that these results are partly a function of the spatial unit of analysis (i.e., counties). The application of the *G* measure tends to favor metropolitan areas because an MSA is large enough to include several adjacent counties with significant patenting activity. Location quotients indicate more concentrations of patenting in Appalachia than the *G* measure, although, again, those concentrations are still often located in metropolitan areas.

As in the case of value-chain employment analyzed in Section 2, the incidence of localized patenting tends to fall into two groups: a set of sectors with evidence of concentration in the region and a set with only minimal concentration. Among the former are patents in the areas of industrial machinery, chemicals and plastics, and metals and metalworking. Industrial machinery patents accounted for most utility patents granted in the region between 1990 and 1999 (6,015 in total, one-quarter of all patent grants). Local concentrations are found in Jamestown, Binghamton, Pittsburgh, and Greenville-Spartanburg (Figure 21). Several counties in Pennsylvania, New York, North Carolina, Tennessee, and Georgia (near Atlanta) also post high location quotients.

Patent grants in chemicals and plastics accounted for slightly less of one-quarter of total patenting activity in Appalachia between 1990 and 1999 (with an overall regional location quotient of 1.2). Most of the significant spatial concentrations of chemicals and plastics patents as measured by the *G* analysis are in areas adjacent to northern Appalachia; there are no *G*-based concentrations in Appalachia itself. High location quotients, however, were found for Appalachian metro counties in Pennsylvania, West Virginia, Tennessee and Alabama (Figure 22). Concentrations of metals and metalworking patents are also located primarily in the north (New York and Pennsylvania, including Pittsburgh, Johnstown, and Jamestown); key border concentrations include Atlanta, Cincinnati, Akron, Reading, Newburgh, Rochester/Buffalo, and Albany (Figure 23).

Figure 21
Spatial concentration: Industrial machinery patent grants, 1990–1999

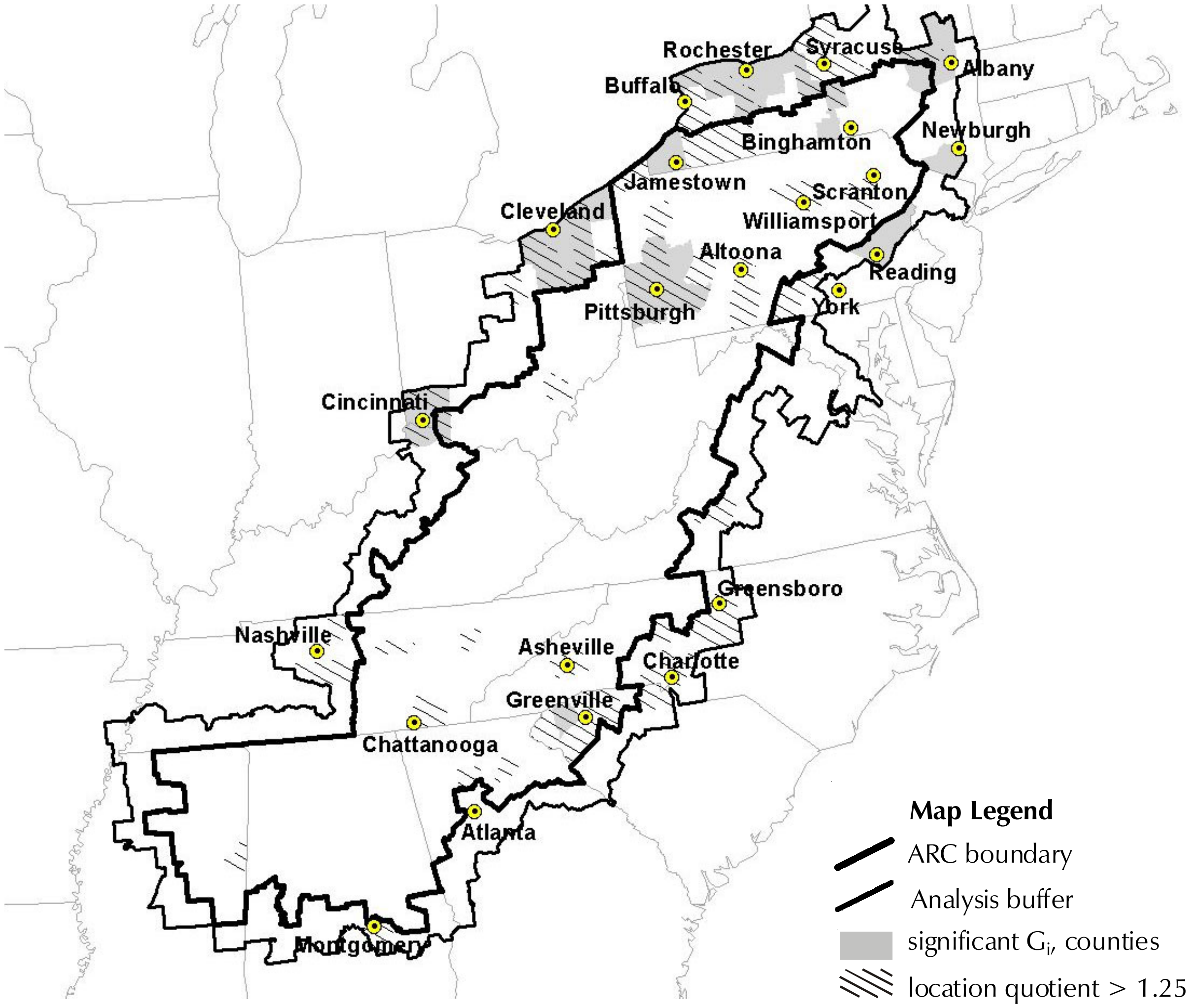


Figure 22

Spatial concentration: Chemicals and plastics patent grants, 1990–1999

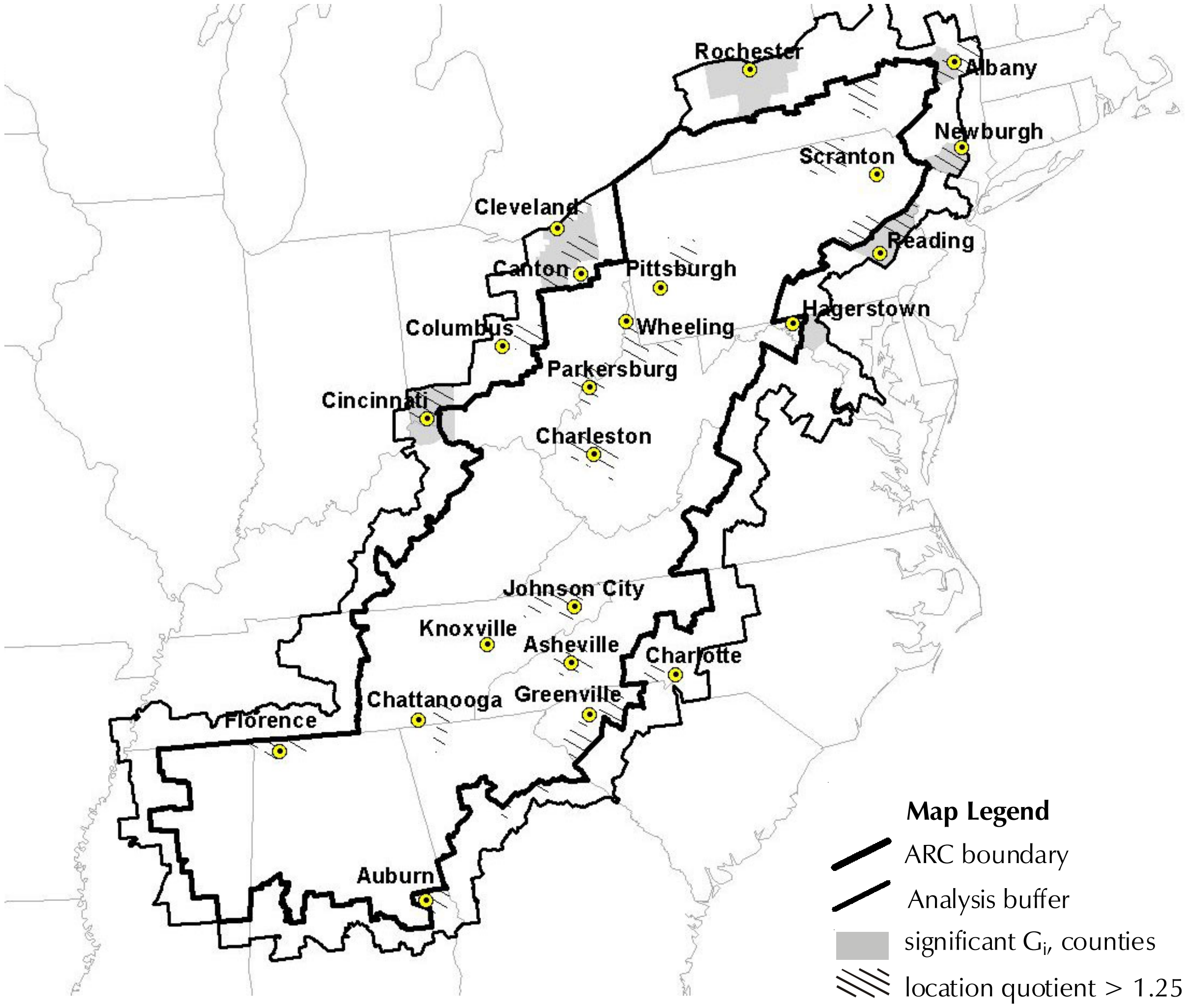
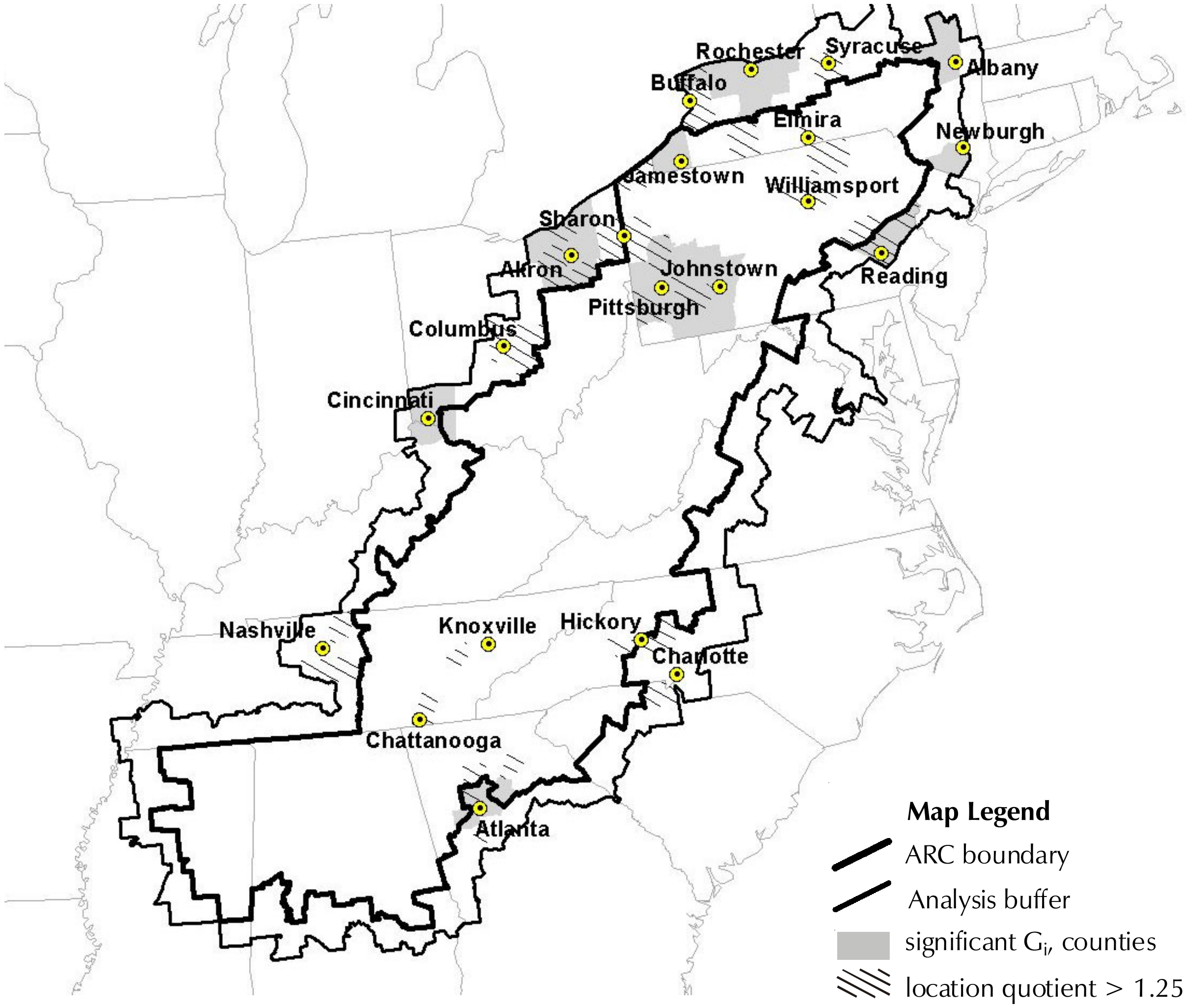


Figure 23

Spatial concentration: Metals and metalworking patent grants, 1990–1999



We found considerably fewer spatial concentrations of patent grants among the remaining technology categories. The most important include:

- In information technology: Binghamton and eastern New York, with high location quotients for Huntsville and the Roanoke area (Figure 24);
- In pharmaceuticals: high location quotients in Birmingham and in Chenango County, New York (home to Proctor & Gamble), with border concentrations near Reading, Washington, Newburgh, and Cincinnati (Figure 25);
- In aerospace: Johnson City and Owego in New York (home to Lockheed Martin facilities), Pittsburgh, Greenville-Spartanburg, and Erie, with key border concentrations in Albany, Rochester, York, Akron, and Middletown, Ohio (Figure 26);
- In scientific instruments: high location quotients in Asheville and Knoxville, with border concentrations in Rochester and Utica, New York (Figure 27);
- In household appliances: greater Atlanta, with border concentrations in New York and Ohio (Figure 28);
- In motor vehicles: high location quotients for the Syracuse area; Scranton, Williamsport, Pittsburgh, and Bedford County in Pennsylvania; Parkersburg in West Virginia; Johnson City and Chattanooga in Tennessee; and border concentrations in the Cincinnati, Akron, Rochester, Albany, Newburgh, and Reading areas (Figure 29).

A significant number of patent grants in the ARC region over the 1990s fell into a variety of miscellaneous categories. Miscellaneous patents accounted for 10 percent of Appalachia's total between 1990 and 1999, compared to 6.5 percent for the U.S. as a whole. Key geographical concentrations are found in Atlanta, Greenville-Spartanburg, and a large region that extends from Rochester south to Elmira and Owego (including a number of non-metro counties). Places such as Pittsburgh, Asheville and Chattanooga also contained counties with high patent location quotients (Figure 30). A summary of the spatial findings by metropolitan area is provided in Appendix Table 10.

Federal Innovation Programs. To assemble a data set of SBIR/STTR/ATP winners in the ARC region, we reviewed program competition announcements for fiscal year 2000 to identify winners with ZIP codes in the 406-county ARC area. As in the case of patents, each grant was mapped to a set of technology areas that roughly are consistent with the value-chain industry classification utilized in Section 2. We then calculated the total number of SBIR/STTR/ATP grants by location for each technology category.[31]

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31. The seven technology area categories were based on a compromise between the competing objectives of 1) minimizing error in the assignment of grants and organizations to specific areas (given incomplete descriptions) and 2) the eventual need to develop a concordance table between the innovative activity described in this section and the industry activity analyzed in Section 2.

Figure 24

Spatial concentration: Information technology patent grants, 1990–1999

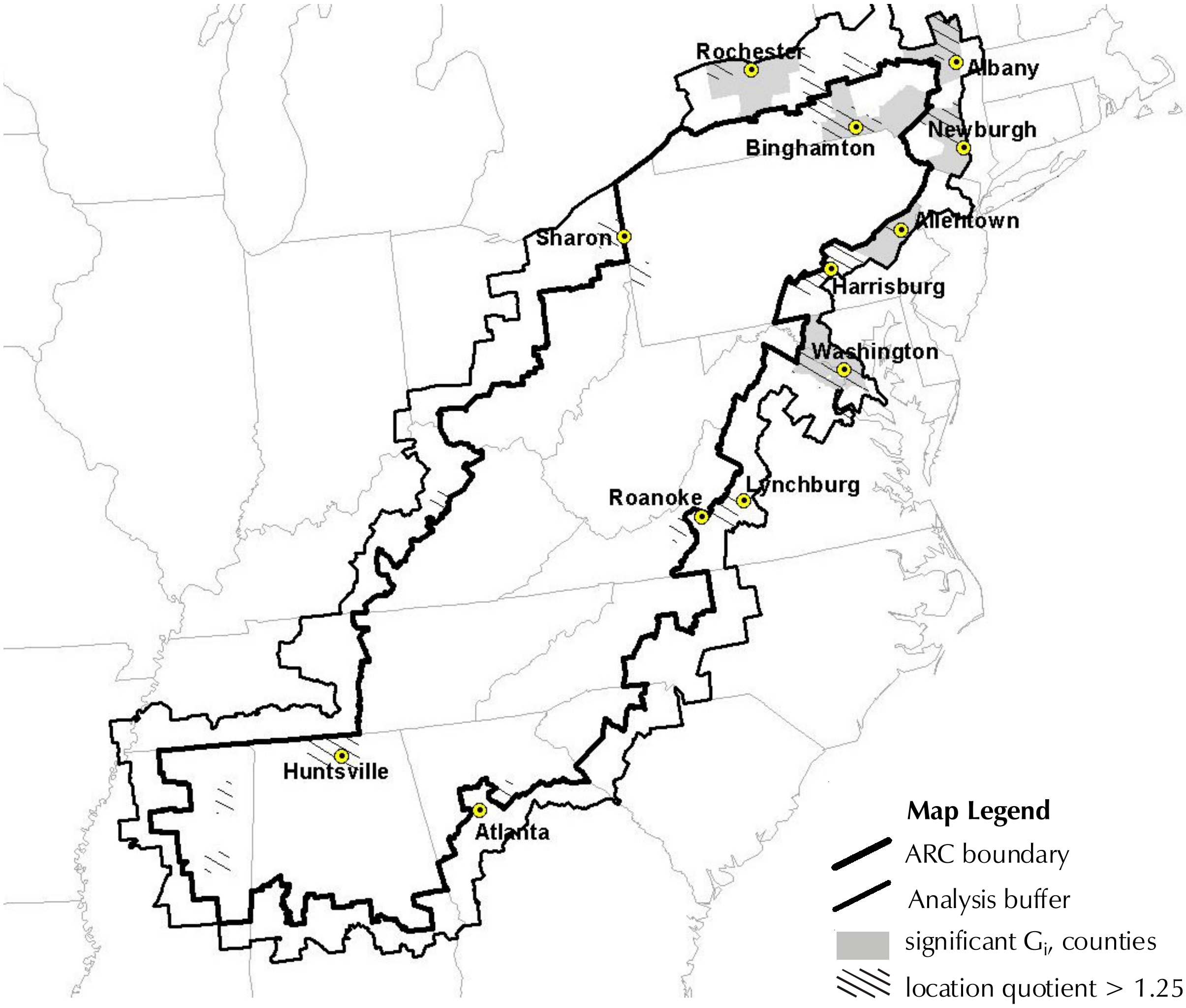


Figure 25

Spatial concentration: Pharmaceuticals patent grants, 1990–1999

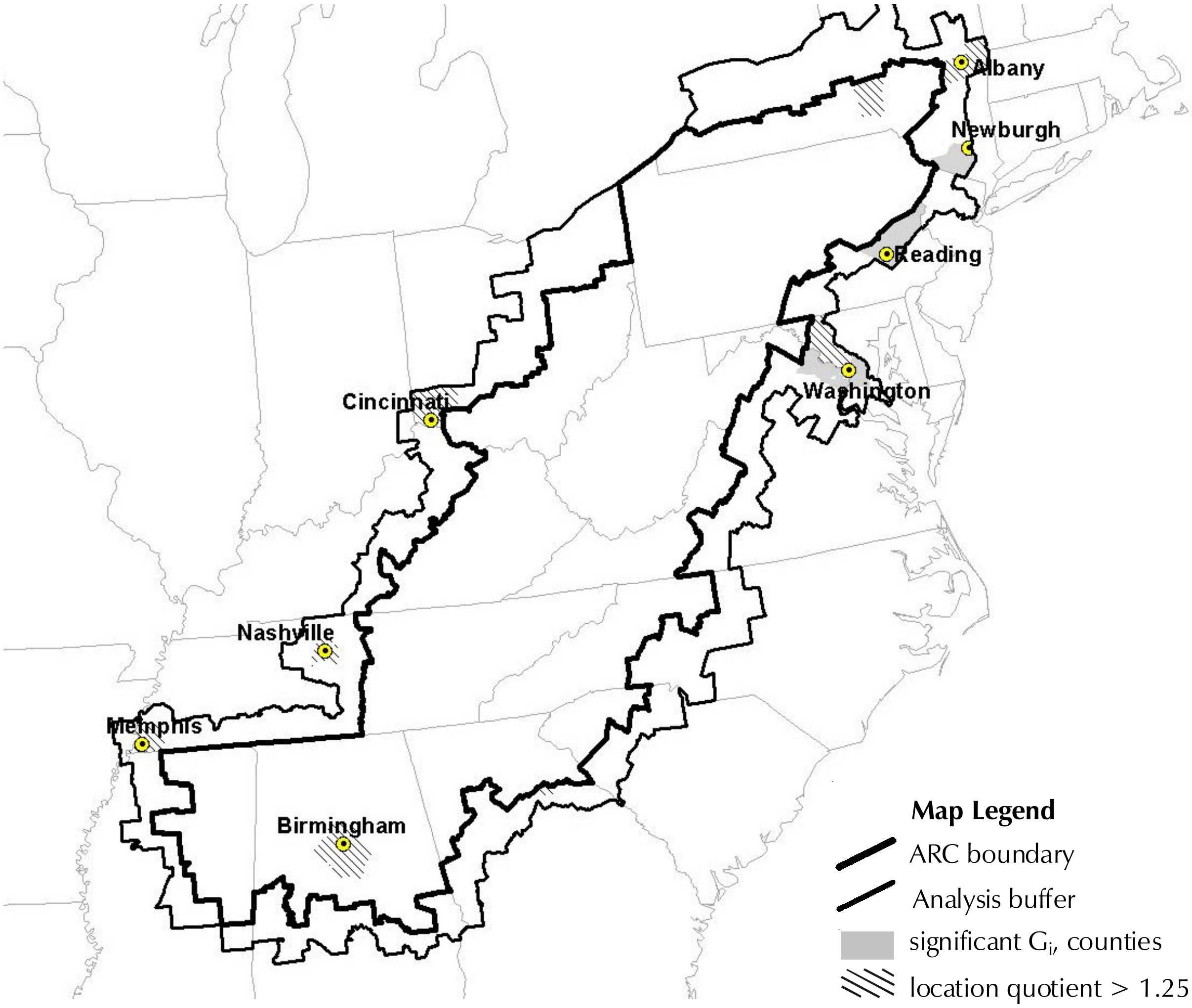


Figure 26

Spatial concentration: Aerospace patent grants, 1990–1999

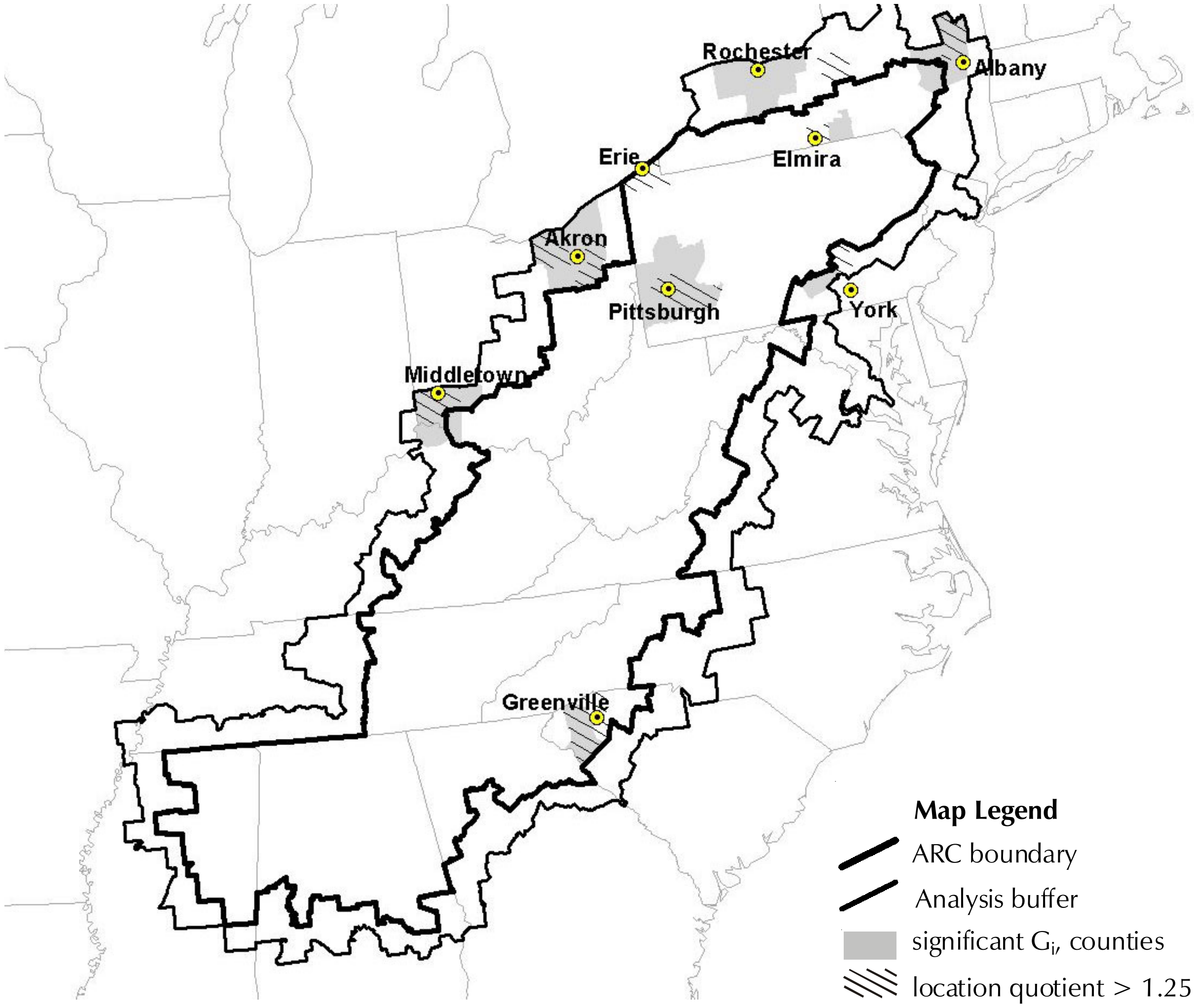


Figure 27
Spatial concentration: Scientific instruments patent grants, 1990–1999

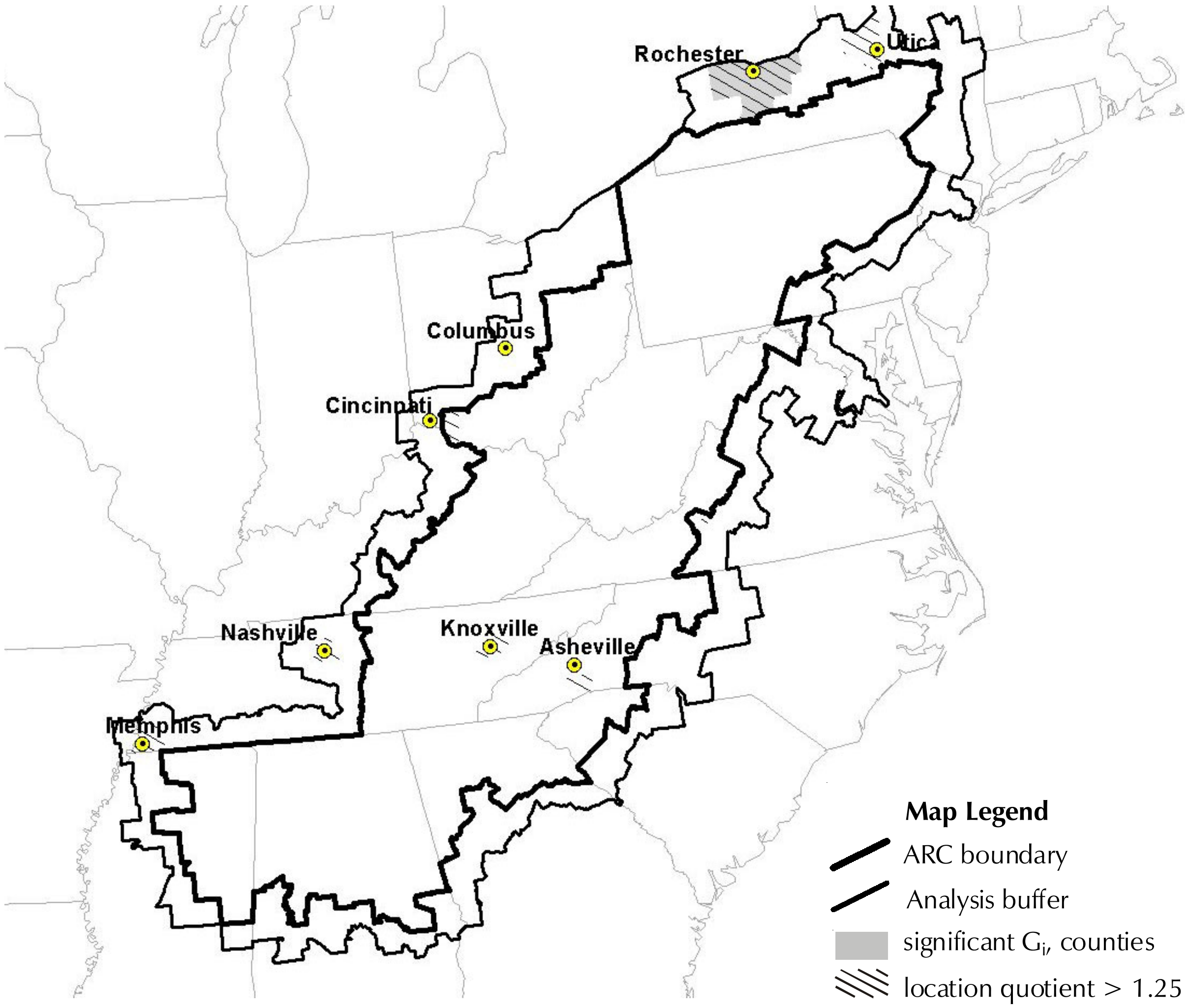


Figure 28
Spatial concentration: Household appliances patent grants, 1990–1999

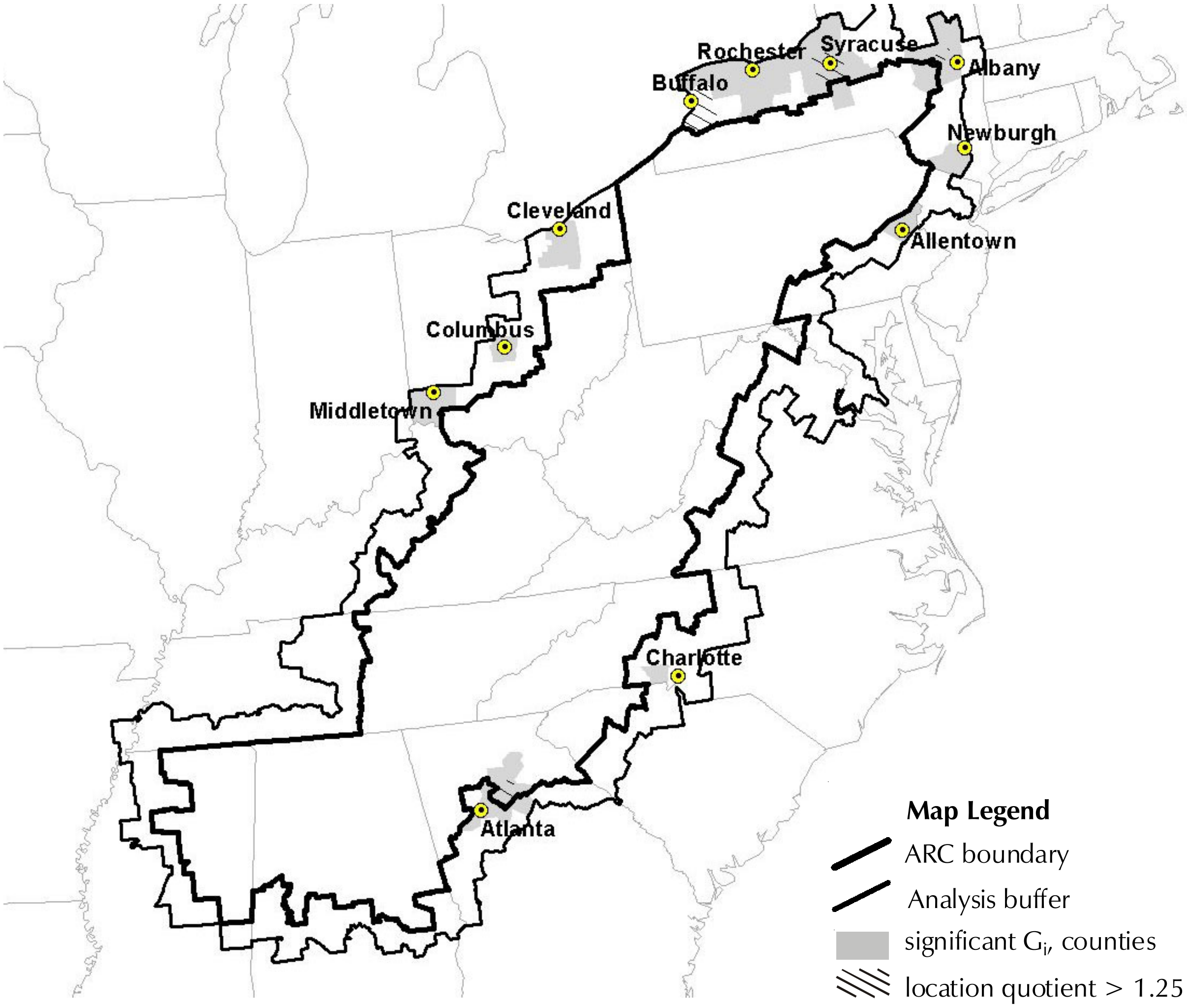


Figure 29

Spatial concentration: Motor vehicles and related products patent grants, 1990–1999

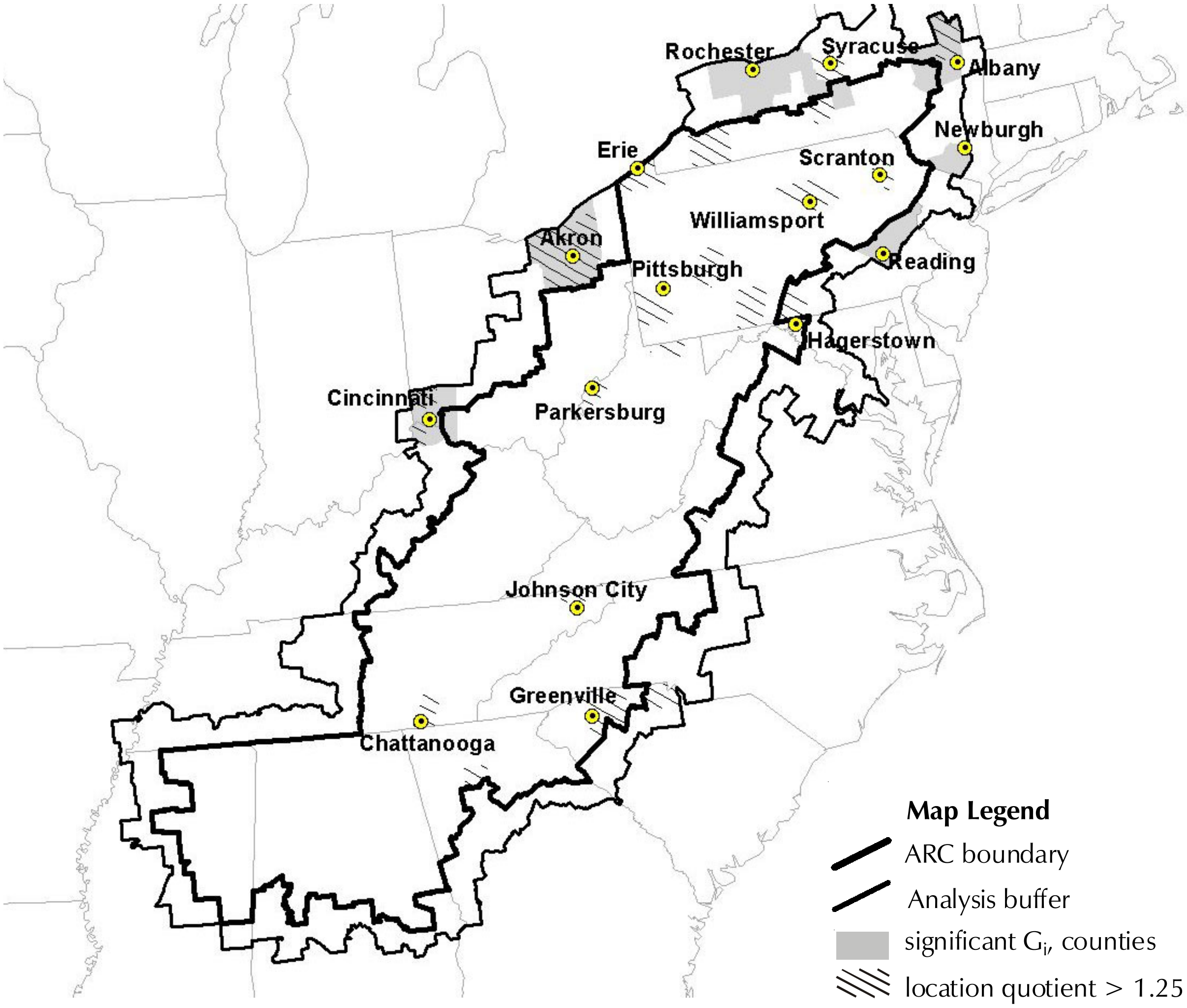
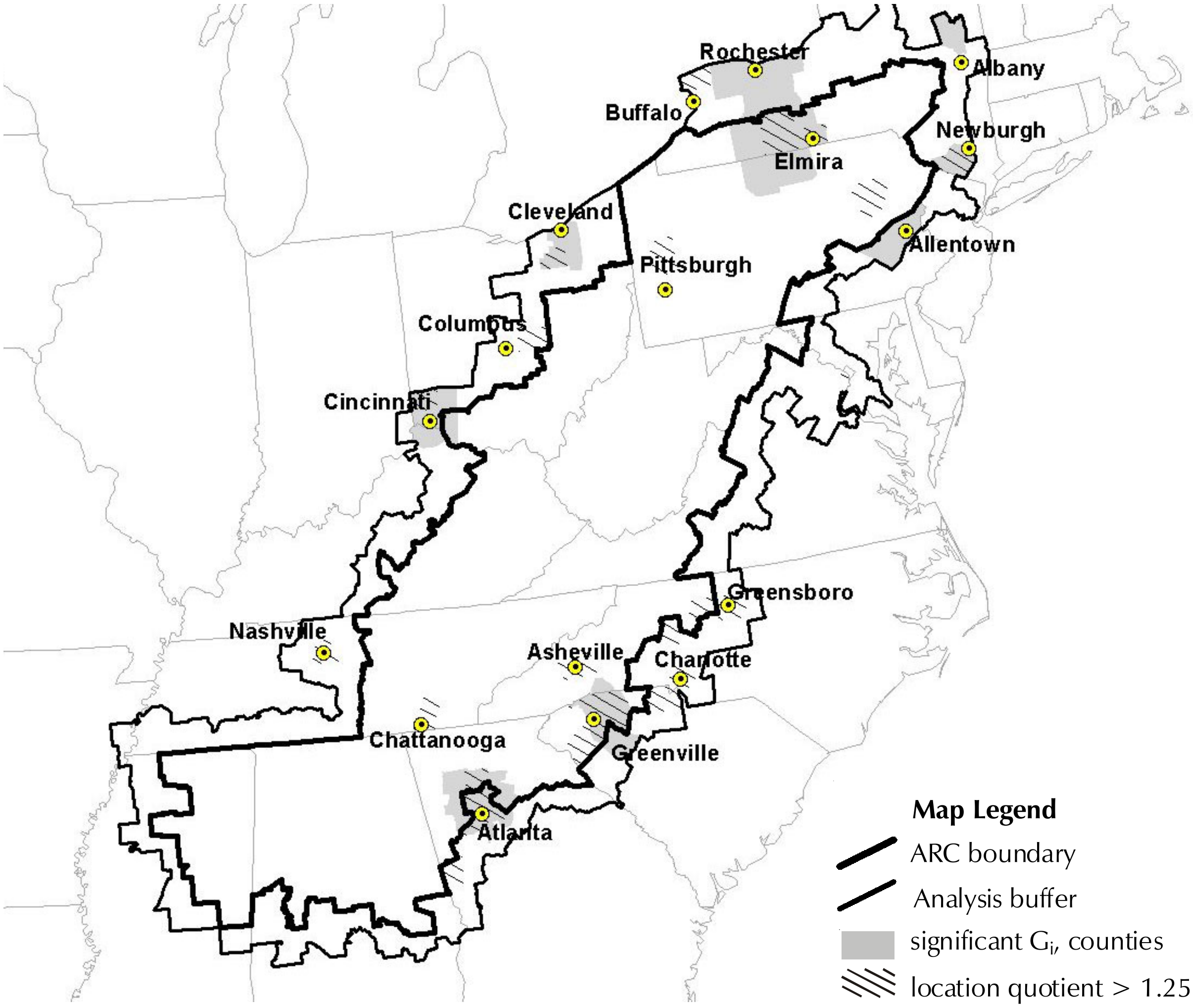


Figure 30

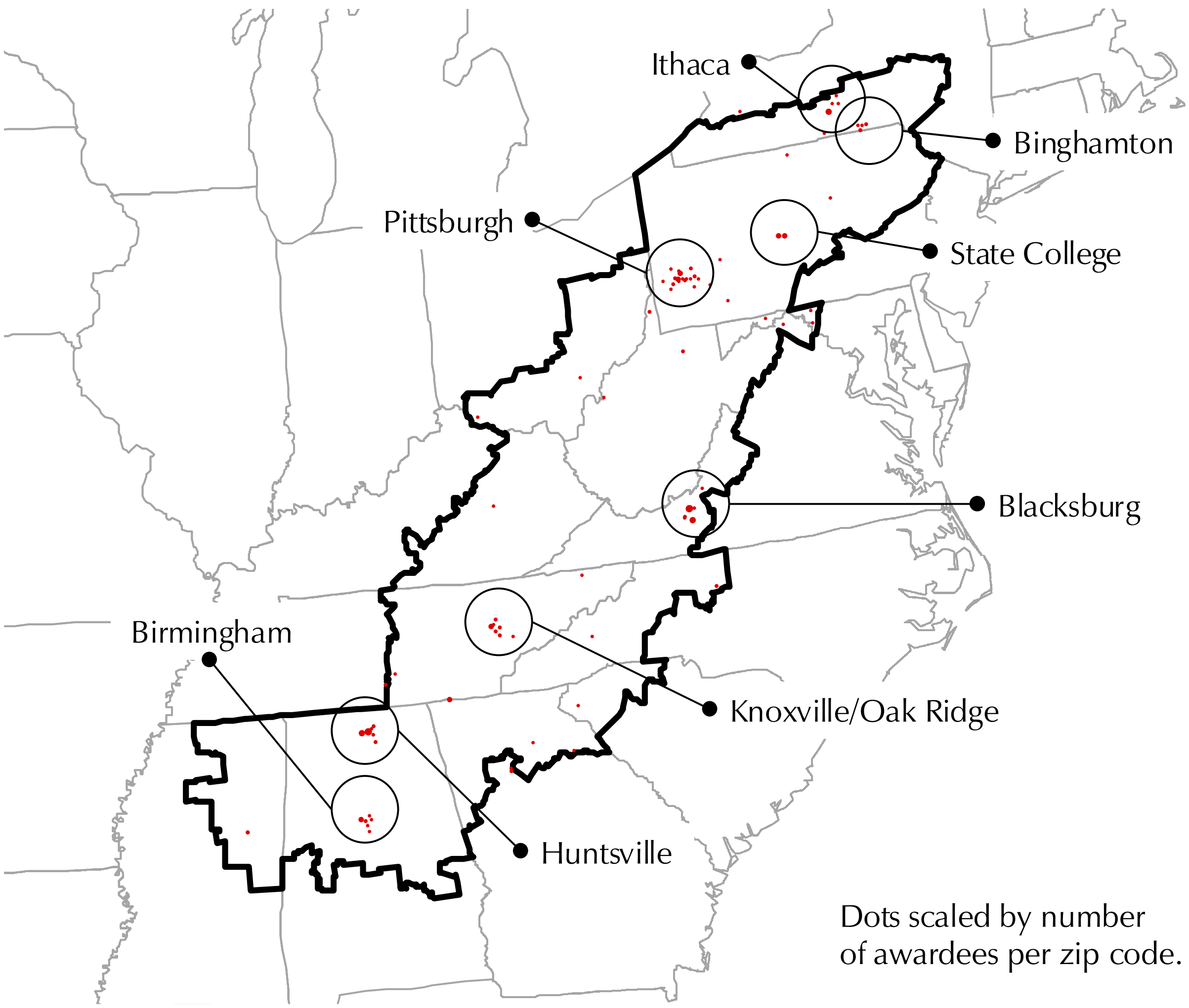
Spatial concentration: Patent grants in all other categories, 1990–1999



There were over 220 SBIR, STTR, or ATP awards given to mostly small, for-profit businesses conducting R&D in the ARC region in FY 2000. The distribution of awards by technology area is as follows: information technology and instruments (52 awards); pharmaceuticals and medical technologies (49 awards); communications services and software (41 awards); aerospace (38 awards); chemicals and plastics (24 awards); industrial machinery (18 awards); and motor vehicles (1 award).[32] Appendix Table 11 is the complete list of SBIR/STTR/ATP award winners for FY 2000.

Figure 31 plots the location of award winners. Awardees were concentrated in a relatively small number of places, especially Huntsville, Blacksburg, Pittsburgh, State College, and Ithaca, New York. Secondary nodes of concentration were Birmingham and Knoxville/Oak Ridge. When disaggregated

Figure 31
SBIR/STTR/ATP award winners in the ARC region, FY 2000
All technology categories



32. Some awards are classified in two categories. Four awards could not be classified. See Appendix Table 11.

by major technology area, a more distinct spatial specialization pattern emerges. The following are the principal nodes of concentration for each major technology area:

- Information technology and instruments: Huntsville, Oak Ridge, Blacksburg, and State College;
- Pharmaceuticals and medical technologies: Birmingham, Pittsburgh, Knoxville/Oak Ridge, and Blacksburg; note that Birmingham and Pittsburgh are the home of universities with prominent medical schools and teaching hospitals;
- Communications services and software: Huntsville, Pittsburgh, Ithaca, and Starkville (the location of Mississippi State University);
- Aerospace: a very large percentage of awardees were located in Huntsville, while there were smaller concentrations of awards in Blacksburg, State College, Chattanooga, and Ithaca;
- Chemicals and plastics: Pittsburgh, Blacksburg, Knoxville/Oak Ridge, and Huntsville.

Industrial machinery is the technology area with the most widely dispersed awardees. While minor nodes are found in Huntsville, Pittsburgh, and Blacksburg, there were one or two awardees in a number of other places. There were no SBIR/STTR/ATP awards in the ARC region in 2000 in the area of household appliances.

3.1.2 State Science and Technology Programs

State government-funded organizations involved in technology-based economic development and technology diffusion are an important element of Appalachia's science and innovation base. While such programs do not generally engage in R&D themselves, they often support science and innovation by diffusing new ideas and technology or providing assistance with technology-related problems facing smaller firms.

In this section, we discuss programs in Appalachia that are centrally focused on technology issues. For example, we include manufacturing modernization programs but not general business incubators. Also, we consider only state-funded programs; local or regional programs are not included unless they utilize state funding.[33] Where possible, we classified the activity of the program or organization by technology area that corresponds, as closely as possible, with the industrial technology categories utilized in Section 2. However, there are a substantial number of organizations that provide

33. We used several sources to generate a draft list technology-based economic development agencies for each state, including Coburn and Berglund (1995); State Science and Technology Institute staff for a list of contacts within the lead science and technology organization within each state; the membership directory of the National Business Incubator Association (http://www.nbia.org); and each state's web site. We then sent the draft list to the key contact person in the state's lead science and technology organization for review and inclusion of any omitted programs or organizations. This process was implemented in December 2000 and January 2001. Note that a number of new programs that had been announced by several states but were not yet in place are not included in our list.

broad technology-related services to businesses that span a wide range of industries. Such organizations could not be classified into any one technology area.

As might be expected, state S&T initiatives are distributed more evenly geographically than are R&D performers. Many state-funded organizations have as a principal mission the provision of services (technical assistance, consulting, education and training) to a broad region, so the actual delivery of services is even more geographically dispersed than would be suggested by the location of the organizations themselves.[34]

A large share of the state-funded S&T assets are based at smaller branches of public universities or community colleges, rather than concentrated at flagship research universities or in larger metropolitan areas. The smaller branch universities are intended to increase the number of state residents with access to higher education. Likewise the placement of technical assistance, support, and training functions at non-research public universities and community colleges is meant to target technology-based small- and medium-sized businesses located in more peripheral areas. Appendix Table 12 reports the full list of state-funded science and technology organizations we were able to identify. Industrial machinery is easily the most common technology focus. Within the ARC region, there are at least thirty different locations of technical assistance services targeted to that general industry, reflecting an emphasis on manufacturing modernization and process innovation in some of the region's traditional industry sectors (textiles, apparel, furniture, and metals).

Two technology areas are particularly important given projections for growth in related industries: information technology and biotechnology. State programs and initiatives targeted at those areas appear to be very few in the ARC region. There are only twelve programs focused primarily on the information technology industry (either instruments or communications services and software): four in West Virginia, two in Virginia, two in Alabama, and one each in Georgia, Ohio, Pennsylvania, and New York. It is notable that we were not able to identify any major IT-related extension or tech transfer programs in the Appalachian regions of Kentucky, Tennessee, North Carolina, South Carolina, and Mississippi. In the case of biotechnology, we identified three programs that receive some state support: the Georgia Biotechnology Center, the Edison Biotechnology Institute in Ohio, and the Cornell Institute for Biotechnology and Life Sciences.

3.2 Appalachia's Higher Education Infrastructure

The higher education and training component of Appalachia's knowledge infrastructure in the sciences and engineering fields is comprised of the over 250 universities, colleges, and institutes that offer degree programs in fifteen technology-related disciplines. The literature on technology-related regional

34. Unfortunately, we were not able to obtain detailed data on the location of clients or actual service delivery.

growth has long emphasized the important role major research universities play in conducting R&D, transferring technology, and generating spin-off companies (Bozeman and Crow 1991; Coursey and Bozeman 1993; Lee and Gaertner 1994; Chrisman, Hynes *et al.* 1995). However, four-year teaching universities and colleges and two-year community colleges and institutes are also critical suppliers of necessary human capital and common sites for publicly-funded business modernization programs (Luger and Goldstein 1997). Community colleges, in particular, play a key role both in preparing and upgrading technology workers in a wide range of applied fields and in supplying focused training and modernization assistance to technology-intensive firms.

This section evaluates the human capital dimension of the Appalachia's colleges and universities using the 1997/98 data on degrees granted by program from the U.S. Department of Education's Integrated Postsecondary Education Data System (IPEDS).[35] IPEDS data ultimately derive from the Department of Education's surveys of all postsecondary institutions that participate in federal financial aid programs. The surveys essentially cover every conventional university, college, and community college in the U.S., as well as many specialized trades schools and technical institutes.[36] The IPEDS degree completions data are reported at a very high level of programmatic detail. We aggregated the figures into fifteen disciplinary/program areas that parallel, as much as possible, the National Science Foundation discipline classification.[37] Appendix Tables 13 and 14 detail our classification scheme.

Academic year 1997/98 degree completions at four-year colleges and universities in the 406-county ARC region are reported in Table 15. Consistent with the distribution of degrees nationwide, two fields accounted for just under half of the total 23,635 degrees granted in Appalachia: agricultural sciences/technology and industrial engineering/technology. Indeed, a comparison with the national distribution of degrees by discipline indicates that the overall mix of programs in Appalachian four-year schools parallels the national mix fairly closely. Judging by total degrees completed, Appalachian universities'

35. The Integrated Postsecondary Education Data System (IPEDS), along with all technical documentation, is accessible via the Internet at http://nces.ed.gov/ipeds/index.html.

36. The Department of Education's universe for its completions surveys are all institutions with which it has Program Participation Agreements (PPAs) regarding Title IV federal financial aid programs, or some 9,519 schools in the fifty states and District of Columbia. The 1997/98 overall response rate for the survey (actually two separate instruments) was 74 percent. Four-year institutions responded at 89 percent, two-year schools at 88 percent, and less than two-year institutions at 53 percent. Although responding institutions account for the vast majority of degrees granted, the IPEDS completions data must be regarded as slight undercounts of total degree completions.

37. Degree completions in the IPEDS data are disaggregated by over 550 Classification of Instructional Programs (CIP) codes (see http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=91396). We used judgment and the National Science Foundation science and engineering disciplines as guides to first identify 190 CIP codes as technology-related programs, and then aggregate the 190 selected codes to fifteen substantive categories. The included CIP codes along with their classification to the fifteen aggregate categories are reported in Appendix Table 13. Appendix Table 14 lists the excluded CIP codes.

Table 15

Estimated degree completions, 1997/98, ARC 4-year colleges and universities

4-year public and private postsecondary educational institutions in 406-county ARC region

Aggregated disciplinary area title	Insti-tutions	Degree completions	Pct share	US pct share*
Aerospace Engineering, Aviation Science, & Astrophysics	137	1,346	5.7	6.1
Agricultural Sciences & Technology	149	5,672	24.0	23.8
Basic Medical Science	131	2,286	9.7	8.2
Biochemistry & Biomedical Engineering	10	345	1.5	0.8
Botany, Biology, Bacteriology, & Biotechnology	9	119	0.5	0.5
Chemical Engineering & Technology	13	216	0.9	0.8
Communications & Computer Sciences & Technologies	15	168	0.7	1.5
Environmental Engineering & Controls	21	1,898	8.0	6.0
Forestry Science & Forestry Technology	55	666	2.8	2.5
Geological & Geophysical Engineering	6	126	0.5	0.3
Industrial Engineering & Technology	137	5,455	23.1	28.6
Materials Engineering & Science	64	2,756	11.7	10.9
Mathematics	32	1,245	5.3	3.6
Mechanical Engineering, Engineering Physics & Science, & Systems Engineering	52	712	3.0	3.4
Physics & Nuclear Engineering	80	625	2.6	2.8
TOTAL		23,635	100.0	100.0

Source: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, *Completions* survey, 1997-1998 and *Consolidated* survey, 1998. *Total US completions in disciplinary area as a share of all US completions for 4-year institutions. Disciplinary areas were defined by the authors as aggregates of related Classification of Instructional Programs (CIP) codes. Completions include any degrees or certification programs offered, whether 4 years or less in duration.

programs in basic medical science, environmental engineering and controls, mathematics, materials engineering and science, and biochemistry and biomedical engineering are slightly larger than the national average while industrial engineering and science is significantly smaller than the national average.

As compared to the national average, proportionately more Appalachian students at two-year colleges earn degrees in agricultural sciences/technology, industrial engineering/technology, and mechanical engineering, physics, and systems engineering, while proportionately fewer earn degrees in the computer and communications sciences (see Table 16). That likely reflects the region's orientation toward agriculture and heavy traditional industry. In general, Appalachia's two-year schools are more heavily specialized in a few disciplinary areas than the national average. Four principal disciplines dominate: communications and computer sciences and technologies (50 percent of degrees granted in 1997/98); mechanical engineering, engineering physics, and systems engineering (28 percent); agricultural sciences and technology (11 percent); and industrial engineering and technology (5 percent). Although communications and computer sciences/technology account for half of all technology-related degrees at two-year schools in the region, the share of students earning such degrees is well below the national average of 61 percent.

Table 16

Estimated degree completions, 1997/98, ARC 2-year colleges and institutes

2-year public and private postsecondary educational institutions in 406-county ARC region

Aggregated disciplinary area title	Institutions	Degree completions	Pct share	US pct share*
Aerospace Engineering, Aviation Science, & Astrophysics	2	61	0.5	0.4
Agricultural Sciences & Technology	3	1,288	10.5	2.0
Basic Medical Science	0	0	0.0	0.0
Biochemistry & Biomedical Engineering	3	10	0.1	5.4
Botany, Biology, Bacteriology, & Biotechnology	6	28	0.2	2.3
Chemical Engineering & Technology	10	201	1.6	0.8
Communications & Computer Sciences & Technologies	139	6,168	50.4	60.8
Environmental Engineering & Controls	19	117	1.0	2.7
Forestry Science & Forestry Technology	8	77	0.6	0.3
Geological & Geophysical Engineering	3	103	0.8	0.8
Industrial Engineering & Technology	29	655	5.4	3.4
Materials Engineering & Science	1	12	0.1	0.0
Mathematics	5	16	0.1	0.8
Mechanical Engineering, Engineering Physics & Science, & Systems Engineering	71	3,480	28.4	18.9
Physics & Nuclear Engineering	4	23	0.2	1.3
TOTAL		12,239	100.0	100.0

Source: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System, *Completions* survey, 1997-1998 and *Consolidated* survey, 1998. *Total US completions in disciplinary area as a share of all US completions for 2 year institutions. Disciplinary areas were defined by the authors as aggregates of related Classification of Instructional Programs (CIP) codes. Completions include any degrees or certification programs offered, whether 2-year or less in duration.

Figures 32 and 33 plot the spatial distribution of total 1997/98 degree completions by county. The maps show two things: first, the location of two- and four-year institutions offering degrees in science-related fields (only counties with at least one school are highlighted), and second, the quantity of science and engineering degrees by location. While four-year schools are more evenly distributed throughout the region than two-year schools on the whole, small concentrations of four-year institutions can still be identified (e.g., in Pennsylvania). The dominance of larger institutions such as Penn State in Central Pennsylvania is also evident. Among two-year schools, the extensive programs in North and South Carolina, and to a lesser extent Pennsylvania and Alabama, contrast sharply with the very limited evidence of substantial degree programs in Tennessee, eastern Kentucky, and West Virginia. Indeed, the IPEDS completions data suggest that central Appalachia is relatively poorly served by two- and four-year institutions offering degree programs in technology-related areas.

Many two- and four-year schools in Appalachia are below the national average in terms of "technology intensity," or the ratio of technology-related degree completions to total degree completions. Figures 34 and 35 plot technology intensity in percentage terms by county.[38] Only counties at or above

38. The measure is the ratio of total technology degrees to all degrees in county *i*, expressed as a percent, where degree completions for all schools in the county are summed. Four-year (Figure 34) and two-year (Figure 35) institutions are evaluated separately.

Figure 32

Total degree completions by county, four-year universities and colleges, 1997/98

All technology-related fields

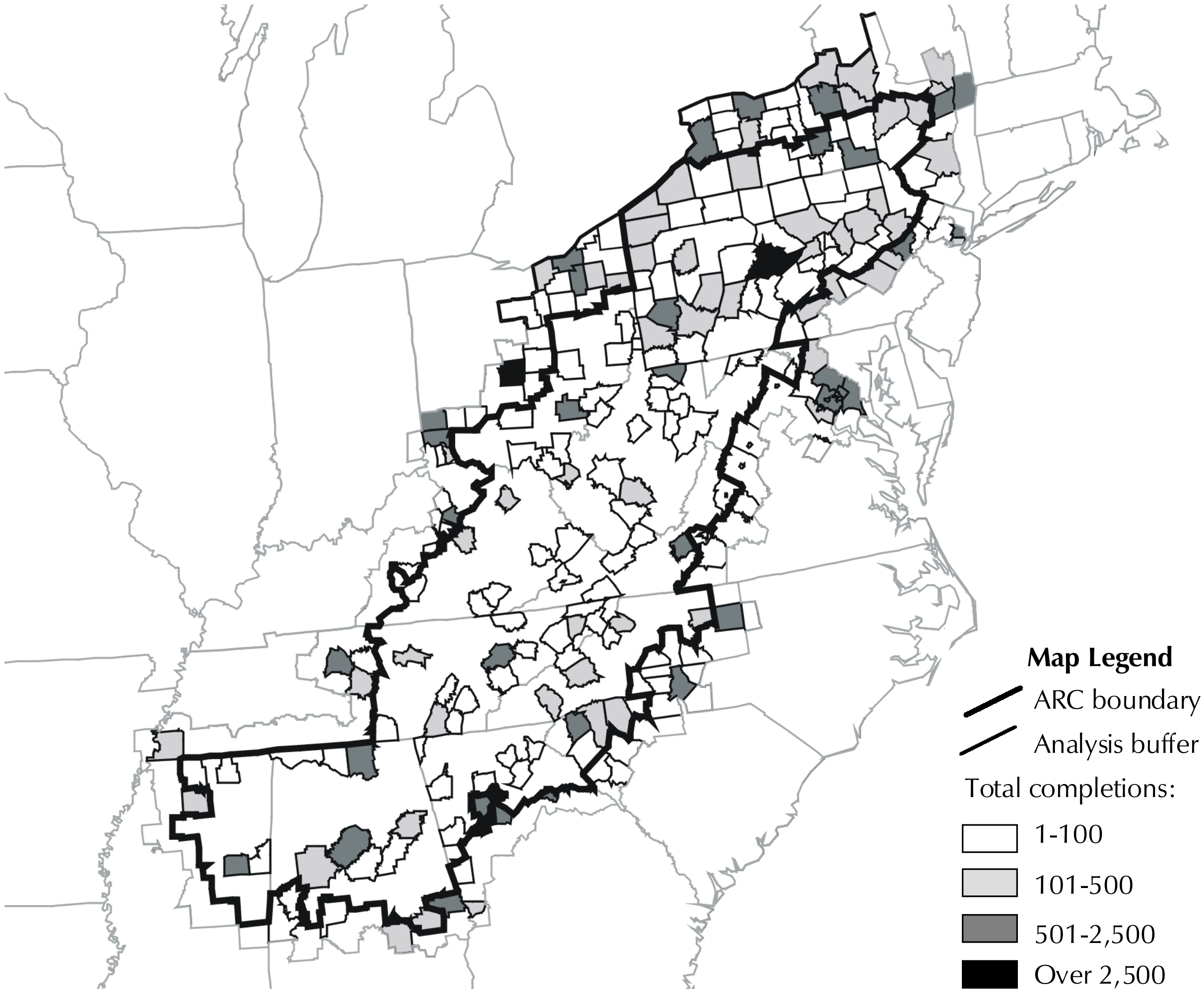


Figure 33

Total degree completions by county, two-year universities and institutes, 1997/98

All technology-related fields

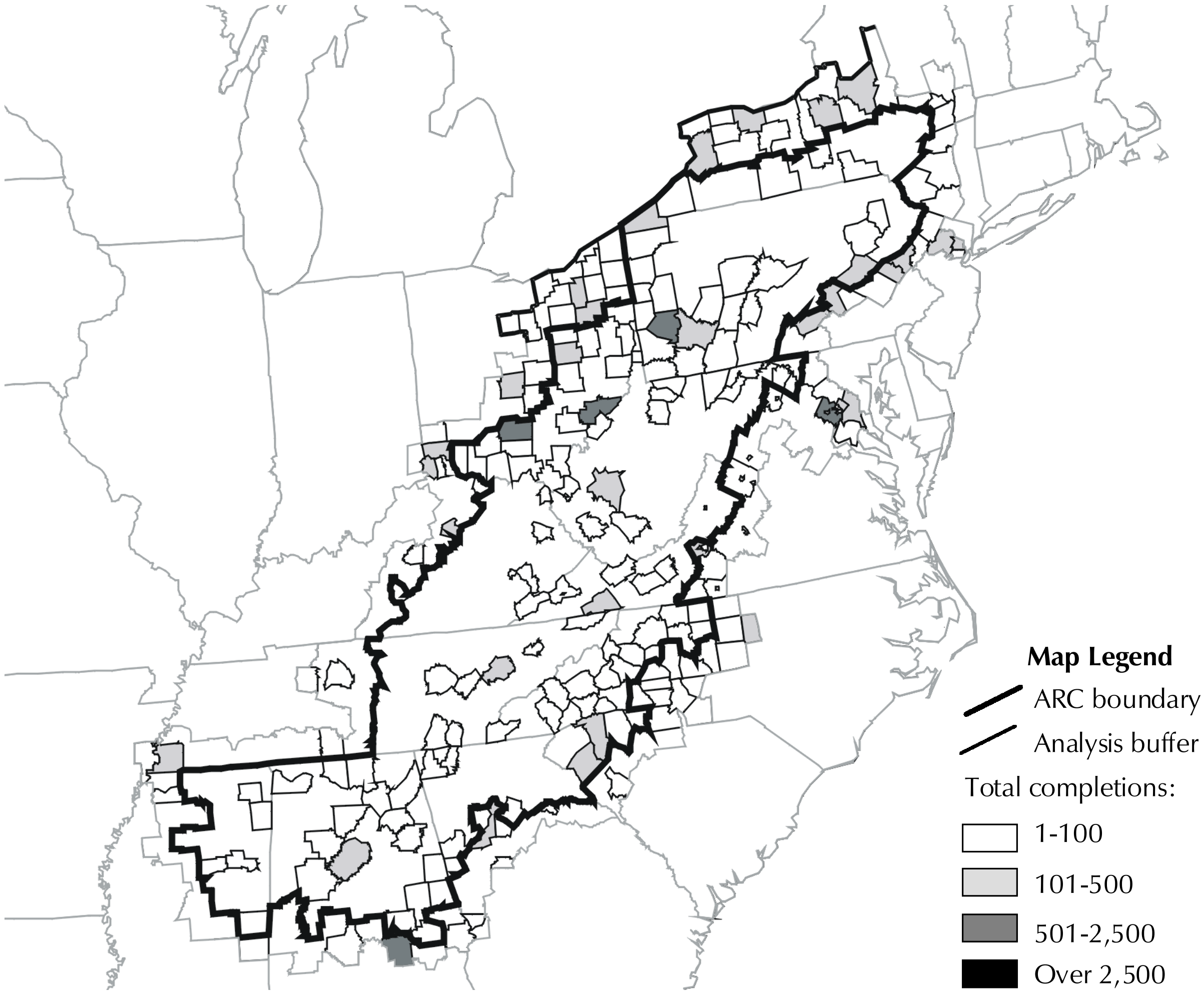


Figure 34

Technology intensity, four-year universities and colleges, 1997/98

Technology degrees as percent share of total degrees

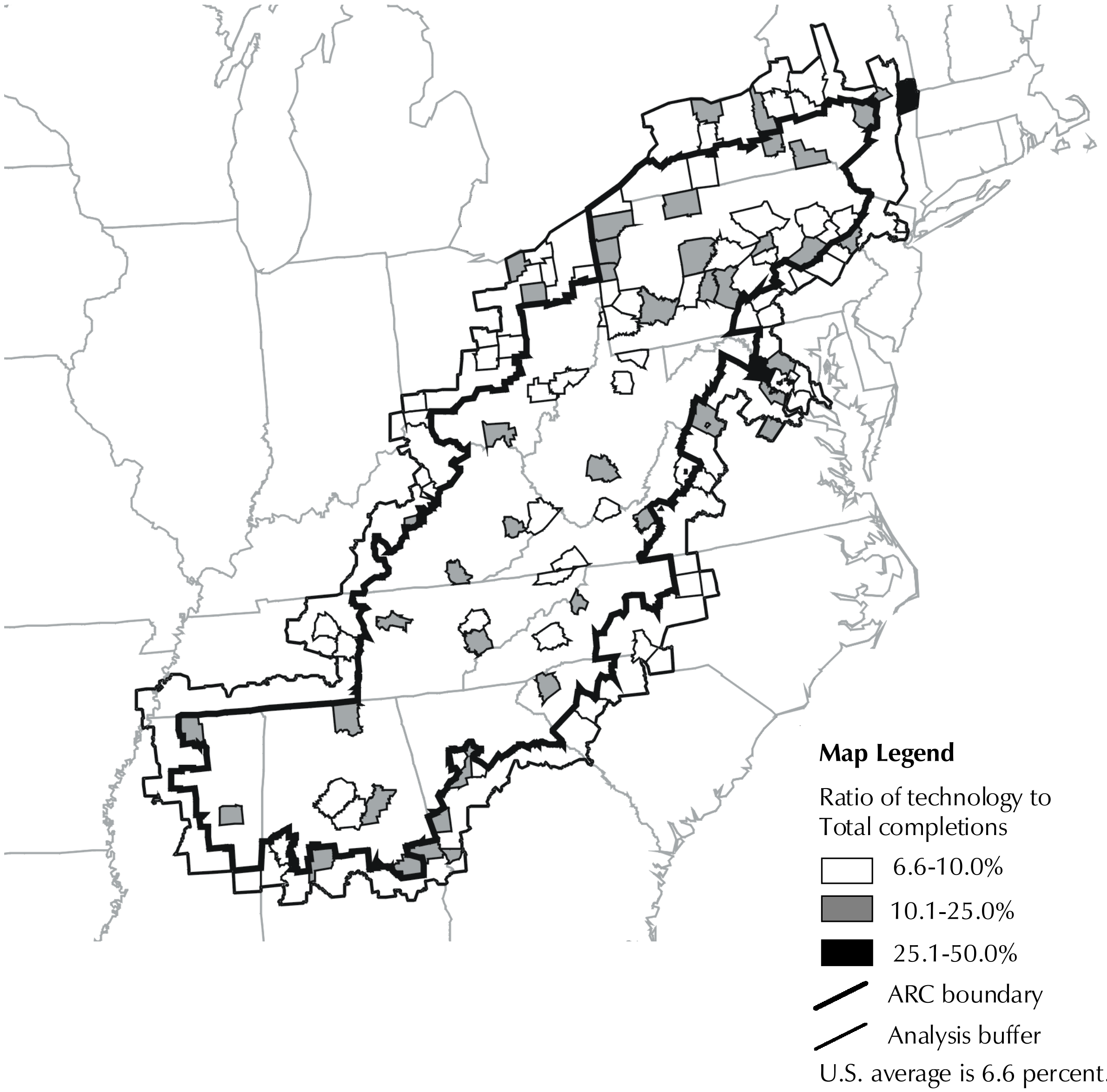
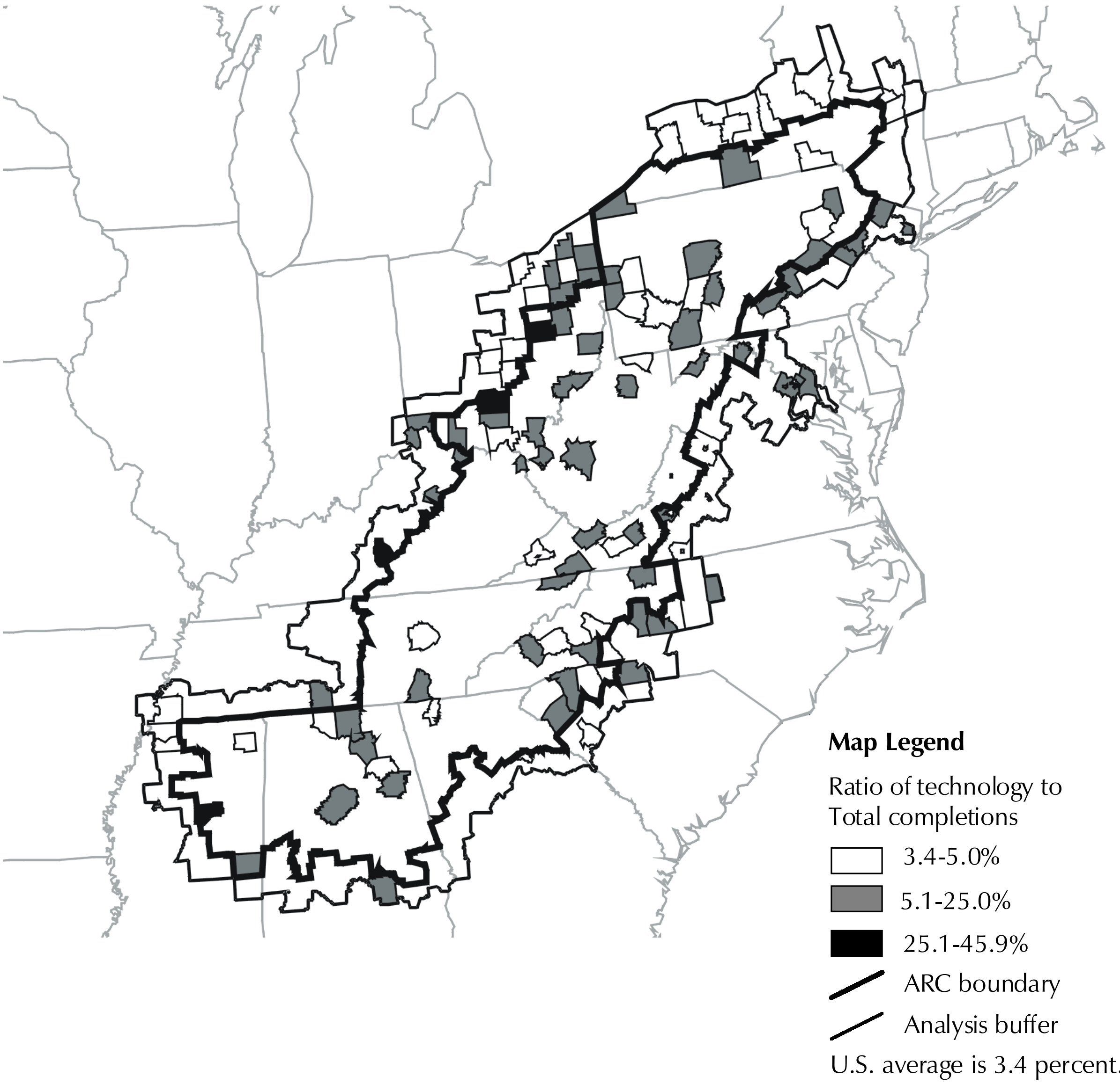


Figure 35

Technology intensity, two-year universities and institutes, 1997/98

Technology degrees as percent share of total degrees



the national average are depicted. Technology-intensive two-year schools are concentrated primarily in Pennsylvania, Virginia, North and South Carolina, West Virginia, and Alabama. Appalachian Tennessee, Kentucky, and northern Georgia have few, if any, technology intensive two-year schools. Again, technology-intensive four-year schools are somewhat more evenly distributed, though such institutions are again concentrated somewhat in Pennsylvania.

3.3 Summary

This section examined the competitive strength and sub-regional geographic distribution of the two major components of Appalachia's knowledge infrastructure: its performers of R&D and its institutions of higher education. The former consist of eighteen research universities and a limited number of other research institutions (such as federal government laboratories), non-profit R&D organizations, state-sponsored technology agencies, and private sector businesses engaged in innovation. The latter are the over 250 universities, colleges, and community colleges offering degree programs and specialized training in fifteen science and engineering-related fields.

We demonstrate that there are clearly a number of nationally competitive R&D strengths within the ARC region. They span a number of technology areas, including all major disciplines of engineering, computer science, mathematics and statistics, and the agricultural sciences. Geographically, most of the R&D strength is located at around fifteen nodes anchored by major research universities, as well as near large federal government labs in Oak Ridge and Huntsville. Unsurprisingly, the large majority of SBIR/STTR/ATP award winners are located within or close to those same nodes. Only state-funded R&D assets aimed at providing direct services to technology-oriented businesses or to individuals seeking advanced training are broadly distributed in the region. The principal R&D nodes tend to have strengths within a number of technology areas, rather than being highly specialized. Thus, even though Huntsville's principal strength is in aerospace, there are also notable strengths in other disciplines including industrial engineering, chemical engineering, and computer science. The following are specific findings from this section:

- Based on national ratings of faculty quality, there are six major nodes of highest competitive strength in the universities in Appalachia (either within or adjacent to the ARC region): Cornell (Ithaca NY), Carnegie-Mellon (Pittsburgh PA), Georgia Tech (Atlanta GA), Emory University (Decatur, Georgia), Penn State (State College PA), and Virginia Tech (Blacksburg, VA).
- While faculty quality rankings indicate that the greatest competitive strengths among Appalachian research universities as a group are oriented toward the physical sciences and engineering rather than the biological and medical sciences, national R&D funding rankings suggests some Appalachian universities are actually very strong in the life sciences disciplines.

- A number of Appalachian universities boast programs that are rising steadily in the national rankings (based on R&D funding and graduate student enrollments). The majority of such "emergent programs" are at Carnegie-Mellon, Georgia Tech, Ohio, Penn State, University of Kentucky, Virginia Tech, West Virginia University, and Mississippi State.
- SBIR/STTR/ATP award winners tend to be concentrated in a relatively small number of places, namely Huntsville, Blacksburg, Pittsburgh, State College, and Ithaca, with smaller concentrations in Birmingham and Knoxville/Oak Ridge. The nature of those federal programs tends to favor locations nearby universities or labs.
- Industrial machinery is easily the most common technology focus among the some 220 SBIR/STTR/ATP awards in fiscal year 2000. That may simply reflect the dominance of the region's traditional industry sectors (textiles, apparel, furniture, and metals).
- There are a great many state-funded technology assistance, transfer, and modernization programs and agencies in the ARC region. Comparatively few, however, are focused on technology areas that are projected to drive significant growth in the next decade: information technology and biotechnology.
- Somewhat surprisingly, Appalachian four-year universities and colleges grant proportionately fewer degrees in industrial engineering and related sciences than their counterparts elsewhere in the U.S. Indeed, based on degree completions in 1997/98, Appalachian universities and colleges grant proportionately more degrees in basic medical science, environmental engineering and controls, mathematics, materials engineering and science, and biochemistry and biomedical engineering than national averages would predict.
- The share of annual degrees awarded in the computer and communications sciences by two-year colleges and institutes in Appalachia is substantially below the national average. That may reflect the comparatively limited job opportunities in IT-related industries in the region (a problem of labor demand) or an inadequate training network for an emerging industry (a problem of labor supply).
- Two- and four-year higher education institutions with an emphasis in technology-related areas are comparatively few in central Appalachia (namely Tennessee, Kentucky, and much of West Virginia).

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.

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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.

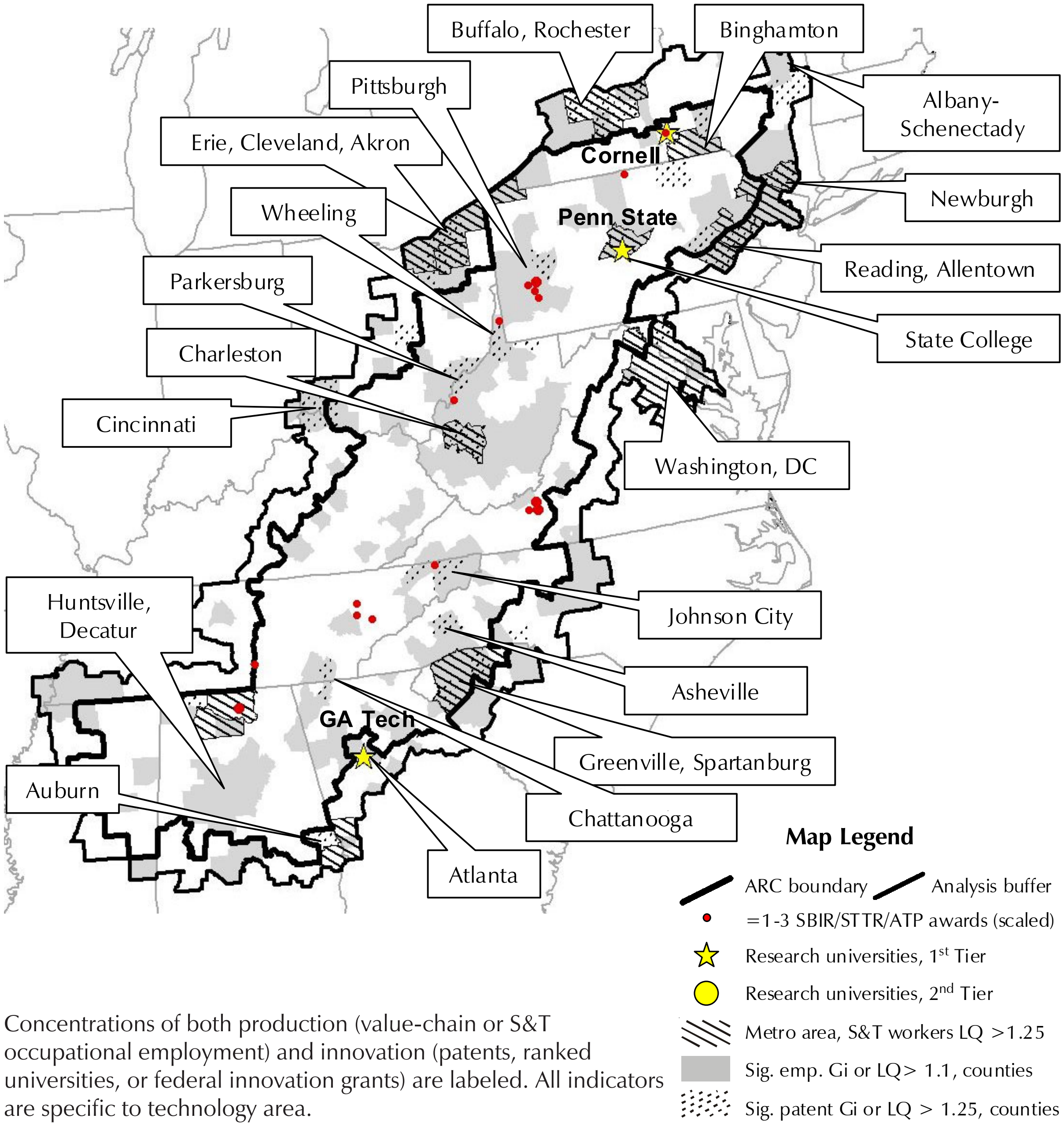
The following results should be interpreted with care and especially with a mind toward the study's specific objectives. We adopted a fairly liberal standard for designating clusters: at least some evidence of joint industrial and innovative activity in the same vicinity. Given the less-developed nature 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

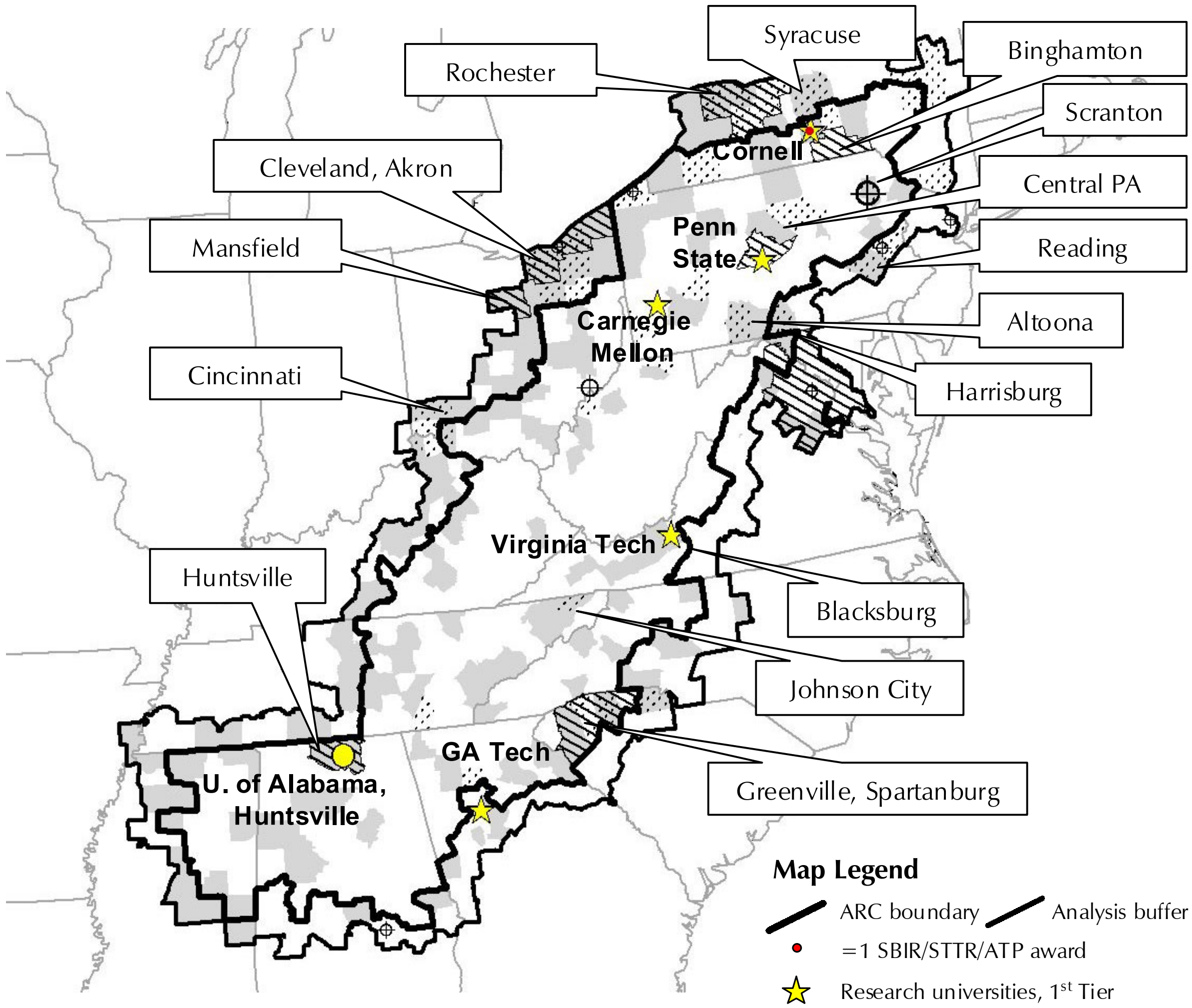
Technology clusters: Chemicals and plastics

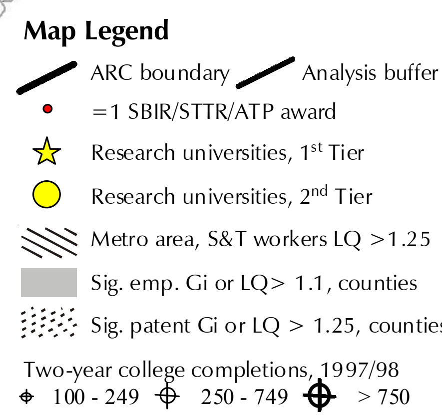


Concentrations of both production (value-chain or S&T occupational employment) and innovation (patents, ranked universities, or federal innovation grants) are labeled. All indicators are specific to technology area.

Figure 37

Technology clusters: Motor vehicles and related

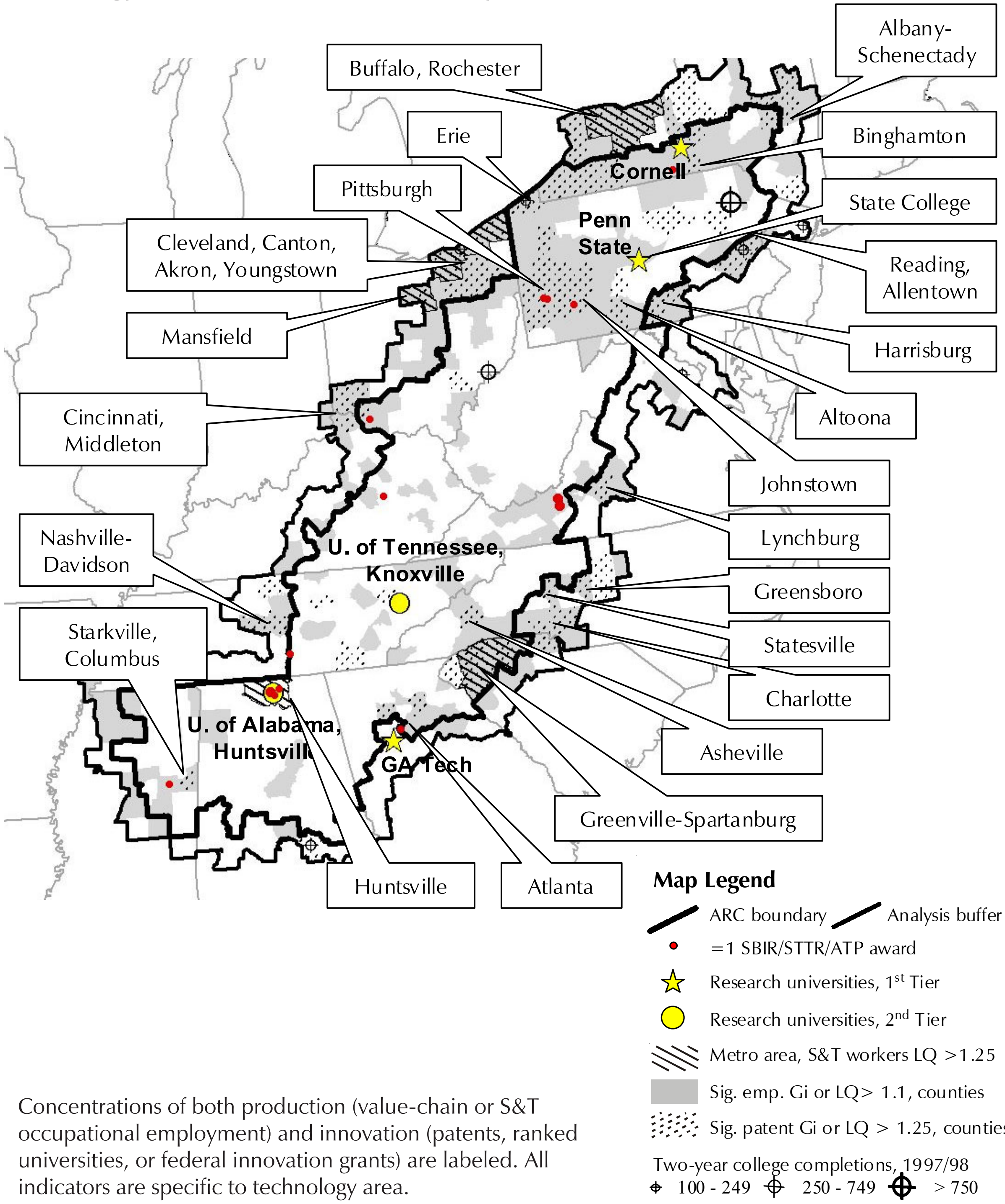




Concentrations of both production (value-chain or S&T occupational employment) and innovation (patents, ranked universities, or federal innovation grants) are labeled. All indicators are specific to technology area.

Figure 38

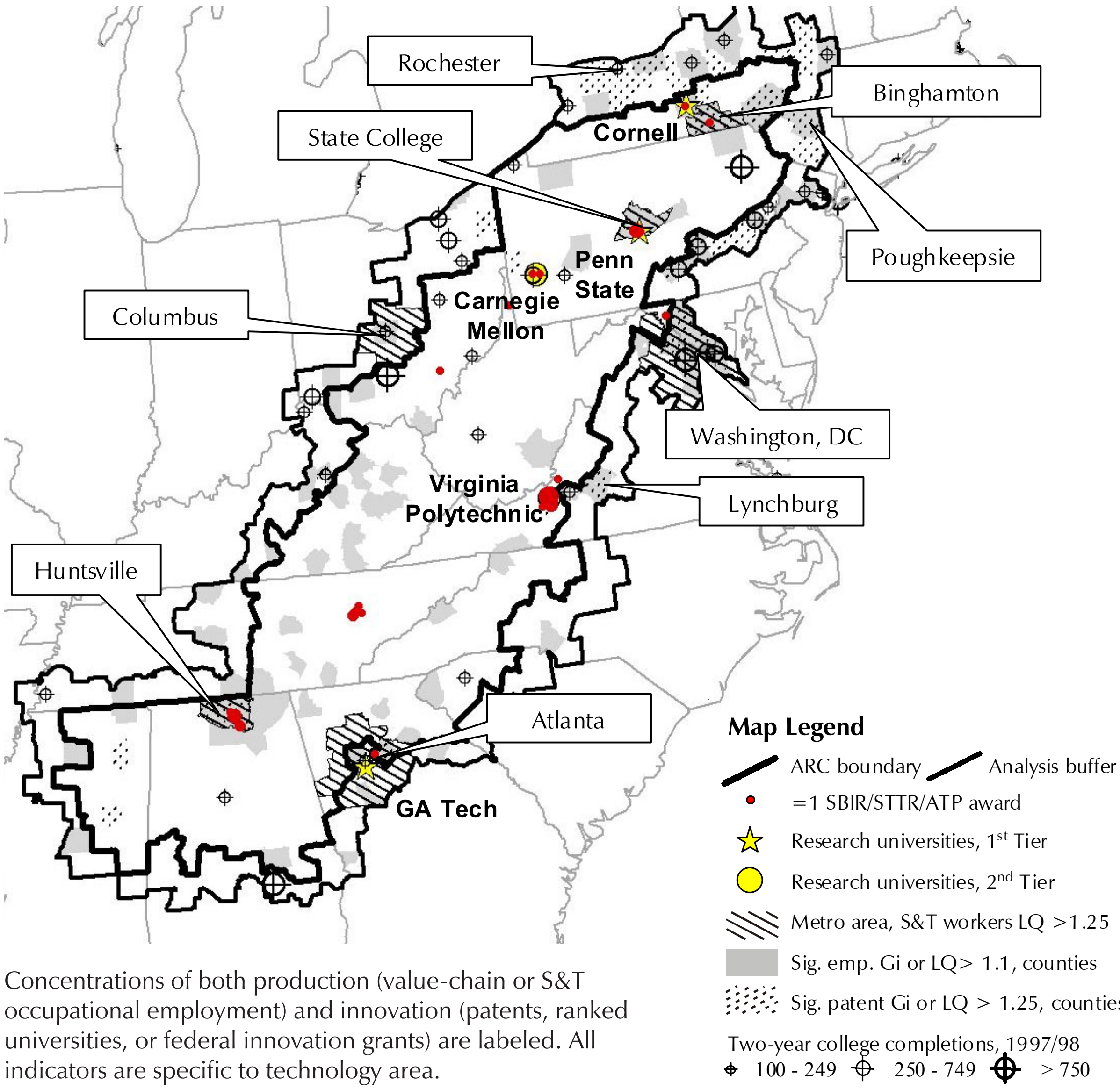
Technology clusters: Industrial machinery



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

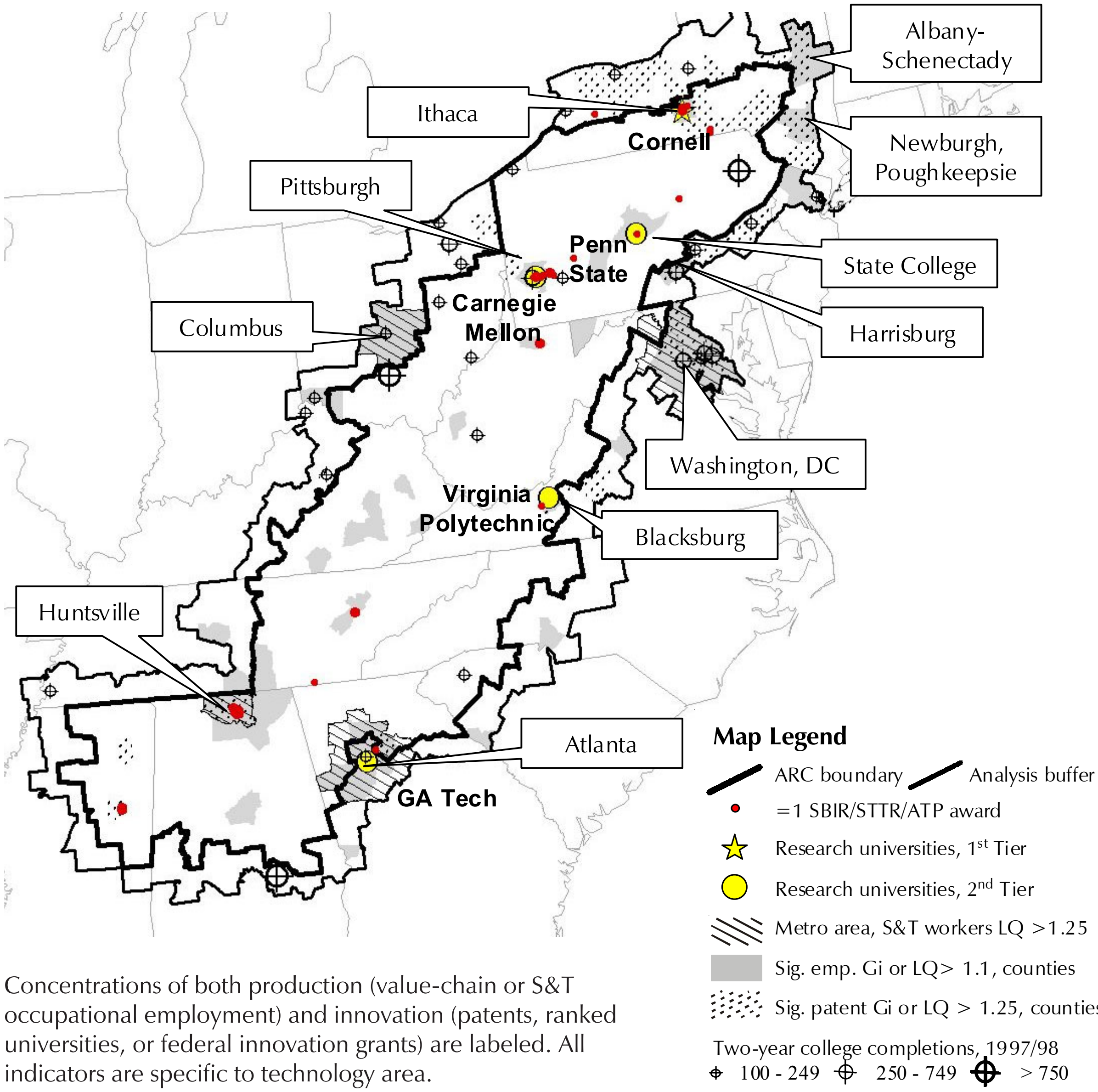
Technology clusters: Information technology and instruments



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.

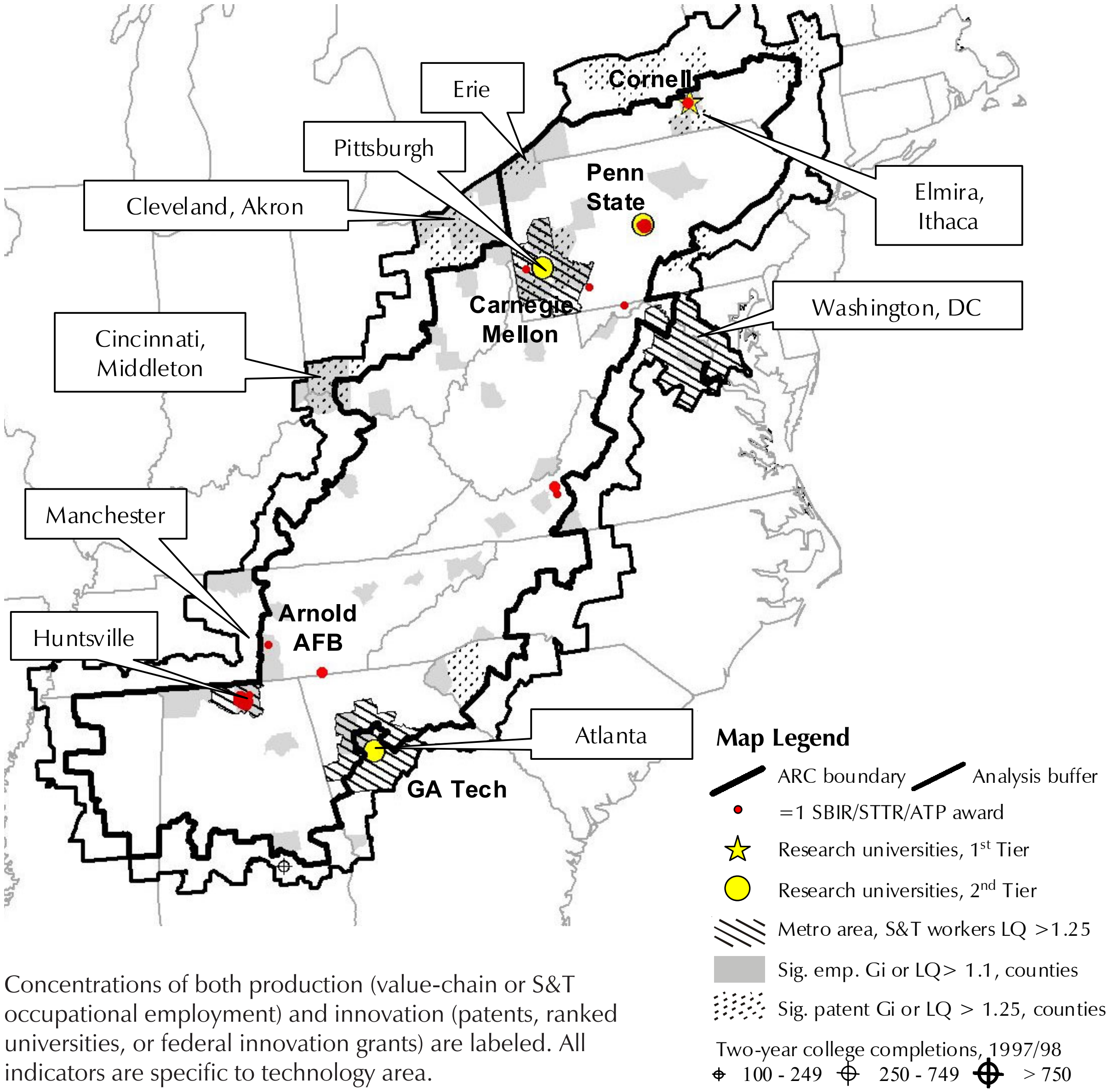
Second, the distribution of clusters throughout Appalachia is highly uneven. Nearly half (45 in total) of the region's technology clusters are located in the northern third of the region (New York, Pennsylvania, and northern Ohio). Only nineteen clusters were identified for central Appalachia (an area 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.

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

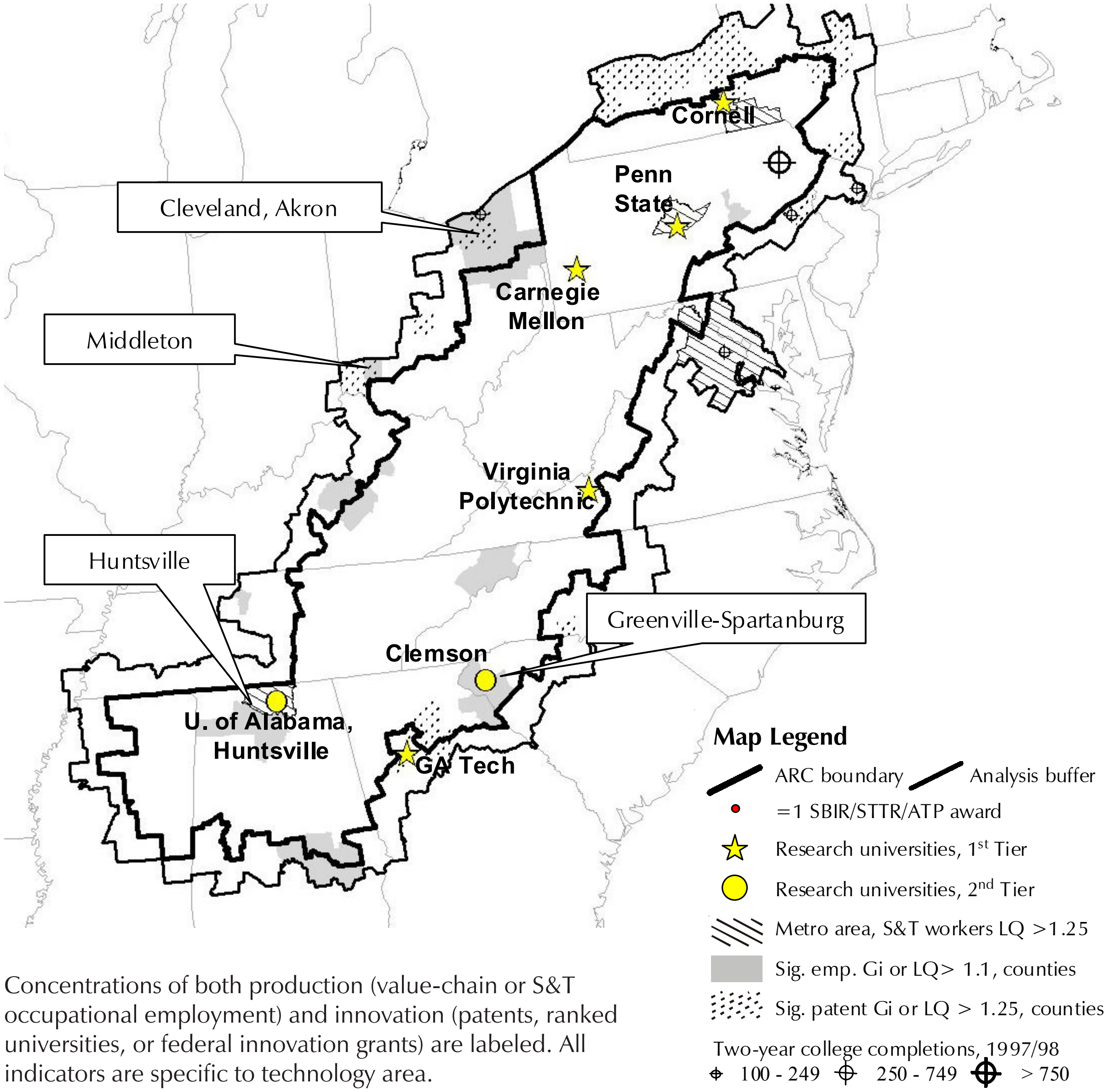
Technology clusters: Aerospace



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

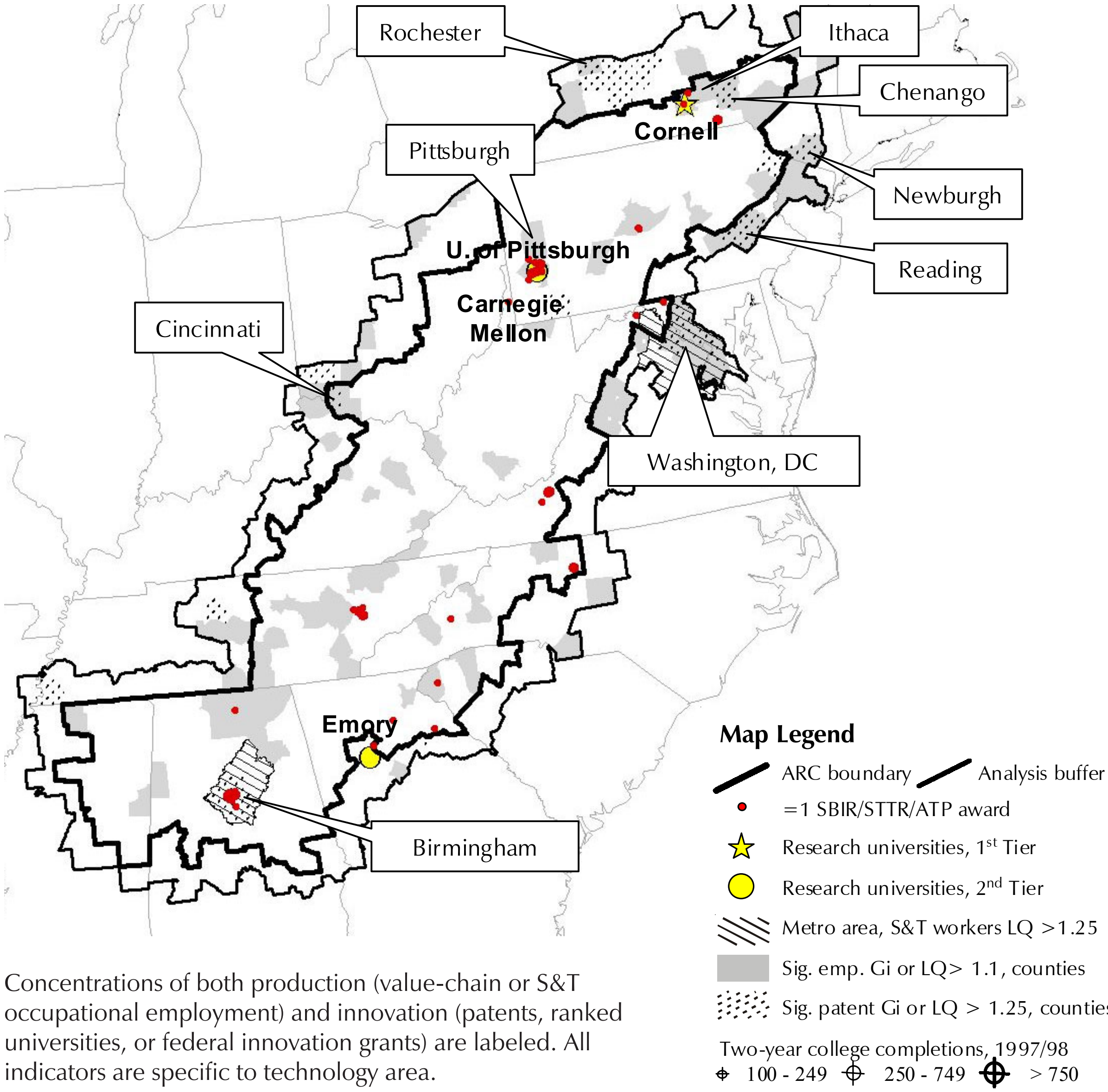
Technology clusters: Household Appliances



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.

References

Amrhein, C G. 1995. Searching for the elusive aggregation effect: Evidence from statistical simulations. *Environment and Planning A* 27: 105-19.

Anderson, G. 1994. Industry clustering for economic development. *Economic Development Review*: 26-32.

Atkinson, R D and R H Court. 1998. *The New Economy Index.* Progressive Policy Institute, Washington, DC.

AUTM. 1991. *AUTM Licensing Survey: Fiscal Year 1991.* Association of University Technology Managers, Inc., Northbrook, IL.

AUTM. 1995. *AUTM Licensing Survey: Fiscal Year 1995.* Association of University Technology Managers, Inc., Northbrook, IL.

AUTM. 1999. *AUTM Licensing Survey: Fiscal Year 1999.* Association of University Technology Managers, Inc., Northbrook, IL.

Bergman, E M and E J Feser. 1999. *Industrial and Regional Clusters: Concepts and Comparative Applications*. Morganton, WV: Regional Research Institute, West Virginia University. http://www.rri.wvu.edu/regscweb.htm.

BLS. 2001. *Occupational Employment and Wages, 1999.* Bureau of Labor Statistics, U.S. Department of Labor, Washington, DC.

Bozeman, B and M Crow. 1991. Technology transfer from U.S. Government and university R&D laboratories. *Technovation* 11: 231-45.

Chrisman, J J, T Hynes and S Fraser. 1995. Faculty entrepreneurship and economic development: The case of the University of Calgary. *Journal of Business Venturing* 10: 267-81.

Coburn, C M and D Berglund. 1995. *Partnerships: A Compendium of State and Federal Cooperative Technology Programs.* Battelle Memorial Institute, Columbus, OH.

Cortright, J. 2001. *New Growth Theory, Technology and Learning: A Practitioner's Guide.* U.S. Economic Development Administration, Washington, DC.

Coursey, D and B Bozeman. 1993. University-industry cooperative R&D: Issues and roles in state economic development. In *Economic Development Strategies for State and Local Governments*, edited by R. P. M. a. E. J. Ottensmeyer, 13-25. Chicago: Nelson-Hall.

Czamanski, S. 1974. *Study of Clustering of Industries.* Institute of Public Affairs, Dalhousie University, Halifax, Canada.

Dalsgaard, M H. 2001. Danish cluster policy: Improving specific framework conditions. In *Innovative Clusters: Drivers of National Innovation Systems*, edited by P. den Hertog, E. M. Bergman and D. Charles, 347-60. Paris: OECD.

Davis, S J, J C Haltiwanger and S Schuh. 1996. *Job Creation and Destruction*. Cambridge, MA: MIT Press.

den Hertog, P, E M Bergman and D Charles, Eds. 2001. *Innovative Clusters: Drivers of National Innovation Systems*. Paris: Organisation for Economic Cooperation and Development.

DeVol, R C. 2000. *Blueprint for a High-Tech Cluster: The Case of the Microsystems Industry in the Southwest.* Milken Institute, Santa Monica, CA.

Feser, E, H Goldstein and M Luger. 1998. *At the Crossroads: North Carolina's Place in the Knowledge Economy of the Twenty-First Century.* North Carolina Board of Science and Technology, Raleigh, NC.

Feser, E J and S H Sweeney. 2002. Out-migration, depopulation and the geography of U.S. economic distress. Forthcoming in *International Regional Science Review*.

Feser, E J, S H Sweeney and H C Renski. 2001. A descriptive analysis of discrete U.S. industrial complexes. Working paper, Department of City and Regional Planning, UNC-Chapel Hill.

Fotheringham, A S and D W S Wong. 1991. The modifiable areal unit problem in multivariate statistical analysis. *Environment and Planning A* 23: 1025-44.

Getis, A and J K Ord. 1992. The analysis of spatial association by use of distance statistics. *Geographical Analysis* 24: 189-206.

Glaeser, E L. 2000. The new economics of urban and regional growth. In *The Oxford Handbook of Economic Geography*, edited by G. L. Clark, M. P. Feldman and M. S. Gertler, 83-98. Oxford, UK: Oxford University Press.

Goldberger, M L, B A Maher and P E Flattau. 1995. *Research Doctorate Programs in the United States: Continuity and Change.* National Research Council, Washington, DC.

Griliches, Z. 1990. Patent statistics as economic indicators: A Survey. *Journal of Economic Literature* 28: 1661-707.

Grossman, G M and E Helpman. 1991. *Innovation and Growth in the Global Economy*. Cambridge, MA: MIT Press.

Hecker, D. 1999. High-technology employment: A broader view. *Monthly Labor Review* (June): 18-28.

Jankowski, J E. 1999. *What is the State Government Role in the R&D Enterprise?* Division of Science Resources Studies, National Science Foundation, Washington, DC.

Krugman, P. 1995. *Development, Geography, and Economic Theory*. Cambridge, MA: MIT Press.

Lee, Y and R Gaertner. 1994. Technology transfer from university to industry: A large-scale experiment with technology development and commercialization. *Policy Studies Journal* 22: 384-99.

Lucas, R E, Jr. 1988. On the mechanics of economic development. *Journal of Monetary Economics* 22: 3-42.

Luger, M and H Goldstein. 1997. What is the role public universities play in regional economic development? In *Dilemmas of Urban Economic Development*, edited by R. D. Bingham and R. Mier, 104-34. Thousand Oaks, CA: Sage.

Luger, M I and H A Goldstein. 1991. *Technology in the Garden*. Chapel Hill, NC: University of North Carolina Press.

McCormick, A C. 2001. *The Carnegie Classification of Institutions of Higher Education, 2000 Edition.* Carnegie Foundation for the Advancement of Teaching, Menlo Park, CA. http://www.carnegiefoundation.org/Classification/index.htm.

NCACTs. 1995. *Making Manufacturing and Technology Work for North Carolina.* North Carolina Alliance for Competitive Technologies, Research Triangle Park, NC.

Nelson, R R. 1996. *The Sources of Economic Growth*. Cambridge, MA: Harvard University Press.

O'Malley, E and C Van Egeraat. 2000. Industry clusters and Irish indigenous manufacturing: Limits of the Porter view. *Economic and Social Review* 31: 55-79.

OTP. 2000. *The Dynamics of Technology-Based Economic Development: State Science and Technology Indicators.* Office of Technology Policy, Technology Administration, U.S. Department of Commerce, Washington, DC.

Pivetz, T R, M A Searson and J R Spletzer. 2000. Measuring job flows and establishment flows with BLS longitudinal establishment microdata. Working paper, U.S. Bureau of Labor Statistics, Washington, DC.

Pollak, M. 1999. Counting the S&E workforce: It's not that easy. *Issue Brief*. Washington, DC, Division of Science Resources Studies, National Science Foundation.

Porter, M E. 1990. *The Competitive Advantage of Nations*. New York: Free Press.

Porter, M E. 1998. Clusters and the new economics of competition. *Harvard Business Review*: 77-90.

Porter, M E. 2000. Location, competition, and economic development: Local clusters in a global economy. *Economic Development Quarterly* 14: 15-34.

Rausch, L M. 1998. High-tech industries drive global economic activity. *Issue Brief*. Washington, DC, Division of Science Resources Studies, National Science Foundation.

Romer, P M. 1986. Increasing returns and long-run growth. *Journal of Political Economy* 94: 1002-37.

Romer, P M. 1990. Endogenous technological change. *Journal of Political Economy* 98: s71- s100.

Saxenian, A. 1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.

Schacht, W H. 2002. *Cooperative R&D: Federal Efforts to Promote Industrial Competitiveness.* Congressional Research Service, Washington, DC.

Solow, R M. 1956. A contribution to the theory of economic growth. *Quarterly Journal of Economics* 70: 65-94.

Solow, R M. 1957. Technical change and the aggregate production function. *Review of Economics and Statistics* 39: 214-31.

Tassey, G. 1999. *R&D Trends in the U.S. Economy: Strategies and Policy Implications.* National Institute of Standards and Technology, Washington, DC.

Wallsten, S J. 2000a. The effects of government-industry R&D programs on private R&D: The case of the Small Business Innovation Research program. *RAND Journal of Economics* 31: 82-100.

Wallsten, S J. 2000b. The R&D boondoggle. *Regulation* 23: 12-16.

White, S B, J F Zipp, W F McMahon, P D Reynolds, J D Osterman and L S Binkley. 1990. ES202: The data base for local employment analysis. *Economic Development Quarterly* 4: 240-53.

Wirtz, R A. 2001. Chasing the tail of high-tech. *The Region*, September.

Wood, L and G Bischak. 1999. *Progress and Challenges in Reducing Economic Distress in Appalachia: An Analysis of National and Regional Trends Since 1960.* Appalachian Regional Commission, Washington, DC.

Wrigley, N. 1995. Revisiting the modifiable areal unit problem and the ecological fallacy. In *Diffusing Geography: Essays for Peter Haggett*, edited by A. D. Cliff, P. R. Gould, A. G. Hoare and N. J. Thrift, 49-71. Oxford, UK: Blackwell.

Measures of Concentration and Spatial Association

We apply two different indicators of spatial concentration to data on employment and patents by sector and value-chain: the simple location quotient and the local G statistic (G_i). A location quotient is a basic summary measure of relative size:

$$\left(e_{ij} / e_{it} \right) \div \left(E_j / E_t \right)$$

where e represents employment (or patents) in an Appalachian sub-region, E denotes U.S. employment (or patents), i subscripts the areal unit of analysis (the county), j subscripts sector (or value-chain or occupation), and t denotes total. A location quotient of 1.0 indicates that the share of activity in the county matches the comparable share for the nation. Location quotients significantly above one (e.g., 1.1 or higher in the case of industry employment, 1.25 or higher in the case of patent grants and occupational employment) indicate a specialization in the given category, i.e. that the given sub-region has a larger share of activity than what we would expect based on the prevailing national sectoral mix.

Location quotients can be misleading when applied at small spatial scales. They do not account for the volume of activity in any particular place, only the share. As a result, small, narrowly specialized economies often post high location quotients that yield a spurious picture of relative specialization. Clearly absolute size, and not just relative size, is an important dimension of functional industrial specialization. To offset the problem of high location quotients in very small counties, we plot location quotients only for counties with at least fifty workers in the given industry or fifty patents in the given technology area.

A location quotient only measures concentrated activity within a sub-region rather than across or between neighboring sub-regions. Our second measure of local spatial concentration, the G_i statistic, measures concentrations of activity both within and across jurisdictional boundaries. The G_i is essentially a share-based measure of spatial concentration, i.e. the amount of activity in a multi-unit region divided by the total activity across all units in the nation, measured in standard deviations from the mean. The results are roughly interpretable as *z*-scores along the normal curve. We use a 95 percent significance level to identify sub-regions with significant concentration in given technology areas. We calculate G_i statistics for both ZIP codes and counties.

The measure for areal unit *i* for a given industry cluster is calculated as:

$$G_i^* = \frac{\sum_j w_{ij} x_j - W_i \bar{x}}{s\sqrt{(nS_{1i} - W_i^2)/(n-1)}}, all\ j$$

where *x* is the variable of interest (e.g. employment or patents), $\{w_{ij}\}$ is a spatial weights matrix that defines neighboring areas *j* to areal unit *i*, W_i is the sum of weights in $\{w_{ij}\}$, $\bar{x} = \sum_j x_j \big/ (n-1)$, $S_{1i} = \sum_j w_{ij}^2$ and $s^2 = \left(\sum_j x_j^2 \big/ n-1\right) - (\bar{x})^2$. Although the normality of G_i^* depends partially on the number of neighbors (Getis and Ord 1992), we make the common simplifying assumption that G_i^* follows a normal distribution for each county. Significant areas (counties or ZIP codes) are identified as those posting values of 1.96 or greater, the 95 percent significance level from a two-tailed normal distribution.

The first step in calculating G_i^* is to develop a spatial weights matrix $\{w_{ij}\}$. The spatial weights matrix acts first as a filter so that only cluster residual employment of neighboring areas are included in the calculation of local concentration. In this study we use a weighted matrix, with adjacency defined by immediate neighbor areas (counties or ZIP codes) inclusive of the area itself. Non-neighboring areal units are given a weight of zero. The value *x* of neighboring area *j* to area *i* is weighted by the degree of expected interaction between areas *j* and *i*:

$$w_j = \frac{X_i X_j}{\sum_j X_i X_j}$$

where upper-case *X* is total exportable (or basic sector) employment and the denominator is the sum of interactions between areal unit *i* and all its neighboring areas *j*. Dividing by the sum of interactions row-standardizes the matrix, turning each cell's weight into a percentage of the total interactions between adjacent areas. The logic behind the weighting scheme is essentially the notion that larger cen-

1. The gravity specification of the weights is far better at identifying discrete concentrations of activity than the more common binary weights.

ters typically exert a heavier influence on neighbor areas than do smaller centers. There is also an implicit assumption that non-neighboring areas do not interact.[1]

To detect unique clusters of activity in and around Appalachia, we also need a means of controlling for the general tendency of industry to concentrate geographically. To the extent that much commerce serves the local population, we should expect more employment in urban centers simply because there is more activity there to begin with. In this study, we are more interested in finding local concentrations of activity beyond those that might be expected by the general distribution of employment and population.

To do this, we use a procedure we developed for a previous study.[2] The first step is to estimate a linear regression model with sectoral employment (or patents) as the dependent variable and total export-base employment as the sole explanatory variable, where counties or ZIP codes are the units of analysis. The regression predicts local employment (or patents) in the sector or cluster based on the distribution of total export-base employment. The difference between the predicted and actual employment or patents, i.e. the residual, is an estimate of local activity beyond that expected by the overall size of the place. The G_i is then calculated using the residuals to identify areas with significant concentrations of technology-related activity.[3] The residuals constitute that portion of employment in the given sector unexplained by the general distribution of economic activity.

Although not infallible, the residual method tends to successfully exclude very small and overly specialized places, because such places are also likely to have small residuals. A downside is that the approach sometimes misses concentrations that are entirely confined within the borders of a single spatial unit. Thus the reason for comparing results using G_i with findings generated with county-level location quotients.[4] We also calculate G_i based on county-level growth residuals between 1989 and 1998 in an attempt to identify emerging technology clusters.[5]

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2. See Feser, Sweeney *et al.* (2001).

3. In the case of patents, G_i statistics are calculated on the residuals of a linear regression with the number of county patents in a technology sector as the dependent variable, and the average county population between 1990 and 1999 as the independent variable. The residuals correspond to the expected county patenting activity beyond that explained by the population of the county. Because patents are coded to the residence of the inventor, population is a better control than employment.

4. *G* statistics are only calculated for ZIP codes within 60 miles of the ARC region, due to the large number of ZIP codes and the difficulties involved in their computation. Nevertheless, the ZIP codes G_i's are derived using national totals as a baseline and therefore are relative to activity in the entire continental U.S.

5. Reporting G_i values by county or ZIP code does not violate U.S. BLS confidentiality rules since actual employment volumes cannot be derived by examination of the coefficients. The statistical coefficients are actually more informative than raw employment totals in searching for spatial concentration, because they control for the size of the local economy and spillovers across jurisdictions.

Derivation of High Tech Value-Chains

Our goal was to develop a consistent set of value-chains comprised of linked technology-oriented industries. We began by analyzing value-chain relationships via a factor analysis of 1992 U.S. input-output (I-O) data.[6] To do this, we first developed a standard 491 by 491 inter-industry transactions matrix from the detailed industry by commodity benchmark input-output accounts. Specifically, following Czamanski (1974) we formed — from the 491 by 491 matrix of inter-industry transactions, **A** — two matrices, **X** and **Y**, with elements:

$$x_{ij} = \frac{a_{ij}}{a_{+j}}, \qquad y_{ij} = \frac{a_{ij}}{a_{i+}}$$

where a_{ij} is the dollar value of goods and services sold by industry *i* in some period to industry *j*, and a_{+j} and a_{i+} are total intermediate good purchases and sales, respectively, of industries *i* and *j* over the same period. x_{ij} is intermediate good purchases by sector *j* from *i* as a proportion of *j*'s total intermediate good purchases. The columns of **X** are the intermediate input purchasing pattern of each industry *j*, while the rows of **Y** are the intermediate output sales pattern of each industry *i*.

For any two industries (A and B) with the column vectors of **X** defined as $\mathbf{x}_A$, and $\mathbf{x}_B$ and the row vectors of **Y** defined as $\mathbf{y}_A$ and $\mathbf{y}_B$, four correlations on the sales and purchasing vectors of any two industries may be derived (again, following Czamanski): 1) $r(\mathbf{x}_A \bullet \mathbf{x}_B)$ measures the similarity in input purchasing patterns of industries A and B; 2) $r(\mathbf{y}_A \bullet \mathbf{y}_B)$ measures the degree to which A and B possess similar output selling patterns, i.e. the degree to which they sell goods to a similar mix of intermediate input buyers; 3) $r(\mathbf{x}_A \bullet \mathbf{y}_B)$ measures the degree to which the buying pattern of industry A is similar to the selling pattern of industry B, i.e. the degree to which industry A purchases inputs from industries in which B supplies (a second-tier linkage); and 4) $r(\mathbf{x}_B \bullet \mathbf{y}_A)$ measures the degree to which the buying pattern of industry B is similar to the selling pattern of industry A, i.e. the degree to which industry B purchases inputs from industries in which A supplies. A linkage matrix, **L**, comprising the largest of these four correlations for each pair of sectors, summarizes the degree of linkage between and among

6. The base input-output data are from the *Benchmark Input-Output Accounts of the United States*, 1992 (Washington, DC: U.S. Department of Commerce), accessible via the Internet at http://www.bea.doc.gov/bea/dn2/i-o.htm.

all 491 sectors. To derive a group of technology-intensive value-chains, we reduced **L** to represent only SIC sectors commonly identified as technology-intensive.[7]

To derive the clusters, we wrote a program using SAS software that conducted a factor analysis on the linkage matrix **L** over multiple times, changing the number of components subject to rotation by one on each iteration.[8] The program aided the analysis by sorting the rotated factors by loading, attaching detailed SIC industry labels to each I-O sector, and producing scree plots and tables reporting the relative proportion of variance explained by each component and the size of the associated eigenvalues. After inspecting each set of results in terms of indicators of fit, economic plausibility, and general interpretability, we selected a final model revealing eight components.

Associated with a given component is a reduced set of variables — in this case, sectors — which constitute its key statistical element. The indicator for determining this element is the individual loading, which is a measure of the relative strength of the relationship between a given variable and each derived component. The magnitudes of the loadings therefore determine the membership in each cluster. I-O sectors were generally included in the value-chain if their loading was equal to or exceeded 0.35, though in some cases we eliminated sectors after inspecting underlying input-output patterns in each cluster.[9] All eight components could be interpreted (i.e., labeled) in a straightforward manner by examining underlying input-output linkages. Note that the eight value-chains are not mutually exclusive; any given underlying industry may be a member of multiple chains.

Summary of Data Sources

The following summarizes the principal sources of data used in the report. Manipulations of the data to derive specific indicators are documented in the report proper (and its extensive set of endnotes).

Industry employment and wages. Employment and wage data by sector are from the confidential U.S. Bureau of Labor Statistics Unemployment Insurance Data Base (UDB), used via special permission. The UDB file is constructed from unemployment insurance tax records assembled by the states

7. The following 109 I-O codes concord to 148 technology-intensive SIC industries: I130100, I270100, I270201, I270202, I270300, I270401, I270402, I270403, I270404, I270405, I270406, I280100, I280200, I280300, I280400, I290100, I290201, I290202, I290203, I290300, I300000, I430100, I430200, I450100, I450200, I450300, I460100, I460200, I460300, I460400, I470100, I470200, I470300, I470401, I470402, I470404, I470405, I470500, I480100, I480200, I480300, I480400, I480500, I480600, I490100, I490200, I490300, I490500, I490600, I490700, I490800, I510102, I510103, I510104, I510400, I530200, I530300, I530400, I530500, I530700, I530800, I540100, I540200, I540300, I540400, I540500, I540700, I550100, I550200, I550300, I560100, I560200, I560300, I560500, I570100, I570200, I570300, I580100, I580200, I580400, I580600, I580700, I590100, I590200, I590301, I590302, I600100, I600200, I600400, I610603, I620101, I620102, I620200, I620300, I620400, I620500, I620600, I620800, I620900, I621000, I621100, I630200, I630300, I660100, I730104, I730112, I730302, I770200, I770305.

8. All calculations were performed using SAS Interactive Matrix Language (IML) software as well as the SAS FACTOR procedure. We used a Promax rotation. Promax produces an orthogonal pre-rotation (equivalent to Varimax) followed by an oblique rotation. Oblique rotation is favored when a high degree of overlap across factors is expected.

under the ES-202 program. At the time of study, 1998 was the most recent year available, with reliable data starting in 1989. The primary limitation of ES-202 data is the exclusion of sole proprietorships. ES-202 data are estimated to include some 95 percent of businesses in the U.S. Our national data exclude Alaska, Hawaii, and Wyoming since we lacked permission to use those states' files.

Occupational employment. Metropolitan occupational employment figures are from the 1999 Occupational Employment Statistics files of the U.S. Bureau of Labor Statistics. The data are downloadable from http://www.bls.gov/oes/home.htm.

Faculty quality ratings. The faculty quality ratings are from the National Research Council's (NRC) 1995 *National Survey of Graduate Faculty*. The findings of the survey are reported in the NRC publication *Research-Doctorate Programs in the Untied States: Continuity and Change*, which is available online at http://books.nap.edu/html/researchdoc/. Institutional rankings by discipline are available at: http://books.nap.edu/html/researchdoc/researchdoc_tables.html.

Reputation measures such as that used to determine faculty quality, are inherently subjective and tend to change only very slowly. The NRC notes, however, that pooling raters' responses generates strong consensus on both the strongest and weakest programs, though considerably less agreement exists on programs in the middle range. Further, the NRC recognizes that, "differences in ranked order between two programs may reflect very small, unreliable, or insignificant differences in the actual quality of a program, and should be regarded by readers with great caution."

University research funding. Data on research and development expenditures were obtained through the National Science Foundation's CASPAR and WebCASPAR Database Systems (http://caspar.nsf.gov). The underlying data are from the *Survey of Scientific and Engineering Expenditures at Universities and Colleges*, a survey conducted annually since fiscal year 1972. All science and engineering doctorate-granting institutions and/or all other institutions conducting at least $50,000 annually in separately budgeted R&D are included in the survey. Over the years, approximately 97 percent of more than 500 institutions nationwide participate in the survey. Moreover, NSF estimates that this survey accounts for approximately 98 percent of all academic R&D expenditures in the United States.

Graduate student enrollments. Graduate science and engineering student enrollment data were obtained from the WebCASPAR Database System. The underlying source is NSF's *Graduate Students and Postdoctorates in Science and Engineering (GSS)* survey. Conducted annually since 1975, the GSS survey collects data from close to 100 percent of all institutions granting masters or higher level degrees in science and engineering disciplines.

University patents and gross license income. Data on the number of patents issued to universities and gross license income are from the Association of University Technology Managers (AUTM 1991, 1995, 1999). Participants in the AUTM survey include U.S. universities, hospitals and research institutes, Canadian institutions, and third-party patent management firms. Of the nearly 196 universities surveyed in FY 1995, approximately 62 percent responded. Among the top 100 research institutions (as measured by total federal dollar support), 87 percent responded. See http://www.autm.net/index_ie.html.

Non-university research organizations and labs. Derived from our own independent research along with Coburn and Berglund 1995 and the membership directory of the National Business Incubator Association (http://www.nbia.org).

Utility patent grants by county. Obtained by special request from the U.S. Patent and Trade Office for states with at least one county in the ARC region. Our analysis utilizes patents awarded between 1990 and 1999 (the most recent year available at the time of the study). A full description of the USPTO patent database (along with technical documentation) is available online at http://www.uspto.gov.

SBIR, STTR, and ATP awards by ZIP code. Derived from program competition announcements for fiscal year 2000. See http://www.sba.gov/SBIR/indexsbir-sttr.html.

Degree completions. College and university completions data were complied from the U.S. Department of Education, National Center for Education Statistics' Integrated Postsecondary Education Data System (IPEDS) completions survey (1997–98) and consolidated survey (1998). The IPEDS universe includes all public and private post-secondary educational institutions that have Program Participation Agreements (PPAs) regarding Title IV federal financial aid programs, some 9,519 schools in the U.S. Degree completions in the IPEDS are disaggregated by over 550 Classification of Instructional Programs (CIP) codes. For the 1997–98 survey year, the IPEDS completions survey response rates vary between 89 percent for four-year institutions, 88 percent for two-year schools, and 53 percent for less than two year institutions. Although survey respondents cover the vast the majority degrees granted, the IPEDS completion data technically must be regarded as a slight undercount of total degrees granted. The IPEDS data and associated technical documentation are available online at http://nces.ed.gov/ipeds/.

Appendix Table 1

SIC-Technology classification

SIC	Sector title	SIC	Sector title
	Very technology-intensive		
2830	Drugs	7373	Computer integrated systems design
3570	Computer and office equipment	7374	Data processing and preparation
3660	Communications equipment	7375	Information retrieval services
3720	Aircraft and parts	7379	Computer related services, nec
3760	Guided missiles, space vehicles, parts	8711	Engineering services
3812	Search and navigation equipment	8731	Commercial physical research
3820	Measuring and controlling devices	8733	Noncommercial research organizations
7371	Computer programming services	8734	Testing laboratories
7372	Prepackaged software		
	Moderately technology-intensive		
2810	Industrial inorganic chemicals	3844	X-ray apparatus and tubes
2820	Plastics materials and synthetics	3845	Electromedical equipment
2860	Industrial organic chemicals	3851	Ophthalmic goods
3670	Electronic components and accessories	3861	Photographic equipment and supplies
3711	Motor vehicles and car bodies	8062	General medical and surgical hospitals
3714	Motor vehicle parts and accessories	8071	Medical laboratories
3716	Motor homes	8072	Dental laboratories
3841	Surgical and medical instruments	8090	Health and allied services, n.e.c.
	Somewhat technology-intensive		
2840	Soap, cleaners and toilet goods	3630	Household appliances
2851	Paints, varnishes, lacquers, etc.	3640	Electric lighting and wiring equipment
2873	Agricultural chemicals	3650	Household audio and video equipment
2890	Misc chemical products	3690	Misc electrical equipment and supplies
3510	Engines and turbines	3713	Truck and bus bodies
3530	Construction and related machinery	3715	Truck trailers
3540	Metalworking machinery	3821	Laboratory apparatus and furniture
3550	Special industry machinery	3842	Surgical appliances and supplies
3560	General industrial machinery	3843	Dental equipment and supplies
3610	Electric distribution equipment	4899	Communications services, nec
3620	Electrical industrial apparatus		

Classification from the North Carolina Employment Security Commission.

Appendix Table 2

Metropolitan areas within and bordering Appalachia

ID	Metropolitan area	Location	ID	Metropolitan area	Location
1	Akron, OH PMSA	O	32	Hickory-Morganton-Lenoir, NC MSA	B
2	Albany-Schenectady-Troy, NY MSA	B	33	Huntington-Ashland, WV-KY-OH MSA	I
3	Allentown-Bethlehem-Easton, PA MSA	B	34	Huntsville, AL MSA	I
4	Altoona, PA MSA	I	35	Jamestown, NY MSA	I
5	Anniston, AL MSA	I	36	Johnson City-Kingsport-Bristol, TN-VA MSA	I
6	Asheville, NC MSA	I	37	Johnstown, PA MSA	I
7	Athens, GA MSA	B	38	Knoxville, TN MSA	I
8	Atlanta, GA MSA	B	39	Lexington, KY MSA	B
9	Auburn-Opelika, AL MSA	O	40	Lynchburg, VA MSA	O
10	Binghamton, NY MSA	I	41	Mansfield, OH MSA	O
11	Birmingham, AL MSA	I	42	Memphis, TN-AR-MS MSA	O
12	Buffalo-Niagara Falls, NY MSA	O	43	Montgomery, AL MSA	B
13	Canton-Massillon, OH MSA	B	44	Nashville, TN MSA	O
14	Charleston, WV MSA	I	45	Newark, NJ PMSA	O
15	Charlotte-Gastonia-Rock Hill, NC-SC	O	46	Newburgh, NY-PA PMSA	O
16	Chattanooga, TN-GA MSA	I	47	Parkersburg-Marietta, WV-OH MSA	I
17	Cincinnati, OH-KY-IN PMSA	B	48	Pittsburgh, PA MSA	I
18	Cleveland-Lorain-Elyria, OH PMSA	O	49	Reading, PA MSA	O
19	Columbus, GA-AL MSA	O	50	Roanoke, VA MSA	B
20	Columbus, OH MSA	O	51	Rochester, NY MSA	O
21	Cumberland, MD-WV MSA	I	52	Scranton–Wilkes-Barre–Hazleton, PA MSA	I
22	Decatur, AL MSA	I	53	Sharon, PA MSA	I
23	Elmira, NY MSA	I	54	State College, PA MSA	I
24	Erie, PA MSA	I	55	Steubenville-Weirton, OH-WV MSA	I
25	Florence, AL MSA	I	56	Syracuse, NY MSA	O
26	Gadsden, AL MSA	I	57	Tuscaloosa, AL MSA	B
27	Greensboro, Winston-Salem, High Point MSA	B	58	Utica-Rome, NY MSA	O
28	Greenville-Spartanburg-Anderson MSA	I	59	Washington, DC-MD-VA-WV PMSA	B
29	Hagerstown, MD PMSA	I	60	Wheeling, WV-OH MSA	I
30	Hamilton-Middleton, OH PMSA	O	61	Williamsport, PA MSA	I
31	Harrisburg-Lebanon-Carlisle, PA MSA	B	62	Youngstown-Warren, OH MSA	B

Note: I: MSA entirely contained within the Appalachian region; B: MSA spans Appalachian border; O: MSA completely outside Appalachia, with borders at least 10 miles from region boundary. MSA boundaries correspond to the 1999 definitions released by the Office of Management and Budget.

Appendix Table 3

Spatial concentration of technology-intensive employment in ARC MSAs

(1998, and growth 1989-1998), by degree of technology-intensity

			Very				Moderately				Somewhat			
ID		MSA name	Cnty	Zips	LQ	Gro	Cnty	Zips	LQ	Gro	Cnty	Zips	LQ	Gro
4	I	Altoona, PA MSA											X	
5	I	Anniston, AL MSA												
6	I	Asheville, NC MSA						X	X		X	X	X	
10	I	Binghamton, NY MSA		X	X			X	X			X	X	
11	I	Birmingham, AL MSA					X	X	X	X			X	
14	I	Charleston, WV MSA			X			X	X					
16	I	Chattanooga, TN-GA MSA										X	X	
21	I	Cumberland, MD-WV MSA			X				X					
22	I	Decatur, AL MSA	X						X			X	X	
23	I	Elmira, NY MSA		X				X	X				X	
24	I	Erie, PA MSA									X	X	X	
25	I	Florence, AL MSA											X	
26	I	Gadsden, AL MSA											X	
28	I	Greenville-Spartanburg-Anderson MSA						X	X	X	X	X	X	X
29	I	Hagerstown, MD PMSA										X	X	
33	I	Huntington-Ashland, WV-KY-OH MSA						X	X					
34	I	Huntsville, AL MSA	X	X	X				X			X	X	
35	I	Jamestown, NY MSA					X				X	X	X	
36	I	Johnson City-Kingsport-Bristol, TN-VA MSA					X		X			X	X	X
37	I	Johnstown, PA MSA						X	X		X		X	X
38	I	Knoxville, TN MSA		X	X				X			X	X	
47	I	Parkersburg-Marietta, WV-OH MSA						X	X				X	
48	I	Pittsburgh, PA MSA		X			X	X	X		X	X	X	X
52	I	Scranton–Wilkes-Barre–Hazleton, PA MSA							X				X	
53	I	Sharon, PA MSA										X		
54	I	State College, PA MSA			X				X					
55	I	Steubenville-Weirton, OH-WV MSA						X	X					
60	I	Wheeling, WV-OH MSA						X	X					
61	I	Williamsport, PA MSA										X	X	
2	B	Albany-Schenectady-Troy, NY MSA	X	X	X	X	X	X	X	X		X	X	
3	B	Allentown-Bethlehem-Easton, PA MSA	X				X	X	X		X	X	X	
7	B	Athens, GA MSA						X	X				X	
8	B	Atlanta, GA MSA	X	X	X			X	X			X	X	
13	B	Canton-Massillon, OH MSA									X	X	X	
17	B	Cincinnati, OH-KY-IN PMSA		X	X			X	X	X	X	X	X	
27	B	Greensboro, Winston-Salem, High Point MSA						X	X	X	X	X	X	X
31	B	Harrisburg-Lebanon-Carlisle, PA MSA						X			X	X	X	
32	B	Hickory-Morganton-Lenoir, NC MSA										X	X	
39	B	Lexington, KY MSA		X	X			X	X			X	X	
43	B	Montgomery, AL MSA			X			X				X	X	
50	B	Roanoke, VA MSA			X			X	X			X	X	
57	B	Tuscaloosa, AL MSA					X	X	X	X				
59	B	Washington, DC-MD-VA-WV PMSA	X	X	X	X		X	X			X	X	
62	B	Youngstown-Warren, OH MSA						X	X		X	X	X	
1	O	Akron, OH PMSA				X	X	X		X	X	X	X	
9	O	Auburn-Opelika, AL MSA											X	
12	O	Buffalo-Niagara Falls, NY MSA					X	X	X		X	X	X	

Appendix Table 3 continues next page

Appendix Table 3 *continued*

Spatial concentration of technology-intensive employment in ARC MSAs

(1998, and growth 1989-1998), by degree of technology-intensity

			Very				Moderately				Somewhat			
ID		MSA name	Cnty	Zips	LQ	Gro	Cnty	Zips	LQ	Gro	Cnty	Zips	LQ	Gro
15	O	Charlotte-Gastonia-Rock Hill, NC-SC		X				X	X	X		X	X	
18	O	Cleveland-Lorain-Elyria, OH PMSA				X	X	X	X		X	X	X	
19	O	Columbus, GA-AL MSA			X							X	X	
20	O	Columbus, OH MSA		X	X			X	X	X		X	X	
30	O	Hamilton-Middleton, OH PMSA						X		X	X	X	X	
40	O	Lynchburg, VA MSA			X			X				X	X	
41	O	Mansfield, OH MSA						X				X	X	
42	O	Memphis, TN-AR-MS MSA										X	X	
44	O	Nashville, TN MSA			X				X	X		X	X	
45	O	Newark, NJ PMSA		X	X	X		X	X		X	X	X	
46	O	Newburgh, NY-PA PMSA					X						X	
49	O	Reading, PA MSA	X					X			X		X	
51	O	Rochester, NY MSA		X		X	X	X	X			X	X	
56	O	Syracuse, NY MSA						X	X	X		X	X	
58	O	Utica-Rome, NY MSA						X	X			X	X	

Note: I: MSA entirely contained within the Appalachian region; B: MSA spans Appalachian border; O: MSA completely outside Appalachia, with borders at least 10 miles from region boundary. Cnty: Significant employment G for at least one county in the metro area. Significant employment G for at least one zip code in the metro area. Gro: Significant employment growth G for at least one county in the metro area. LQ: Employment location quotient in excess of 1.1 for at least one county in the metro area.

Appendix Table 4

Technology value-chain classification

SIC	Sector title
Chemicals and plastics	
2812	Alkalies and chlorine
2813	Industrial gases
2816	Inorganic pigments
2821	Plastics materials and resins
2822	Synthetic rubber
2823	Cellulosic manmade fibers
2824	Organic fibers, noncellulosic
2841	Soap and other detergents
2842	Polishes and sanitation goods
2843	Surface active agents
2844	Toilet preparations
2851	Paints, varnishes, lacquers, enamels, etc.
2865	Cyclic crudes and intermediates
2869	Industrial organic chemicals, nec
2873	Nitrogenous fertilizers
2874	Phosphatic fertilizers
2875	Fertilizers, mixing only
2879	Agricultural chemicals, nec
2891	Adhesives and sealants
2893	Printing ink
2899	Chemical preparations, nec
3559	Special industry machinery, nec
3624	Carbon and graphite products
3692	Primary batteries, dry and wet
3843	Dental equipment and supplies
8071	Medical laboratories
8072	Dental laboratories
8092	Kidney dialysis centers
8093	Specialty outpatient facilities, nec
8099	Health and allied services, nec
3610	Electric distribution equipment
3620	Electrical industrial apparatus
Information technology and instruments	
3571	Electronic computers
3572	Computer storage devices
3575	Computer terminals
3577	Computer peripheral equipment, nec
3578	Calculating and accounting equipment
3579	Office machines, nec
3625	Relays and industrial controls
3629	Electrical industrial apparatus, nec
3631	Household cooking equipment
3643	Current-carrying wiring devices
3644	Noncurrent-carrying wiring devices
3661	Telephone and telegraph apparatus
3663	Radio & TV communications equipment
3669	Communications equipment, nec
3672	Printed circuit boards
Information technology and instruments cont.	
3674	Semiconductors and related devices
3675	Electronic capacitors
3676	Electronic resistors
3677	Electronic coils and transformers
3678	Electronic connectors
3679	Electronic components, nec
3694	Engine electrical equipment
3699	Electrical equipment & supplies, nec
3812	Search and navigation equipment
3821	Laboratory apparatus and furniture
3822	Environmental controls
3823	Process control instruments
3824	Fluid meters and counting devices
3825	Instruments to measure electricity
3826	Analytical instruments
3827	Optical instruments and lenses
3829	Measuring & controlling devices, nec
3844	X-ray apparatus and tubes
3845	Electromedical equipment
7371	Computer programming services
7372	Prepackaged software
7373	Computer integrated systems design
7374	Data processing and preparation
7375	Information retrieval services
7379	Computer related services, nec
Industrial machinery	
3511	Turbines and turbine generator sets
3532	Mining machinery
3535	Conveyors and conveying equipment
3536	Hoists, cranes, and monorails
3541	Machine tools, metal cutting types
3542	Machine tools, metal forming types
3546	Power-driven handtools
3547	Rolling mill machinery
3549	Metalworking machinery, nec
3553	Woodworking machinery
3555	Printing trades machinery
3556	Food products machinery
3559	Special industry machinery, nec
3561	Pumps and pumping equipment
3563	Air and gas compressors
3564	Blowers and fans
3565	Packaging machinery
3612	Transformers, except electronic
3621	Motors and generators

Appendix Table 4 continues next page

Appendix Table 4 *continued*

Technology value-chain classification

SIC	Sector title
Motor vehicle manufacturing	
2851	Paints, varnishes, lacquers, enamels, etc.
2893	Printing ink
3519	Internal combustion engines, nec
3531	Construction machinery
3534	Elevators and moving stairways
3537	Industrial trucks and tractors
3548	Welding apparatus
3641	Electric lamps
3645	Residential lighting fixtures
3646	Commercial lighting fixtures
3647	Vehicular lighting equipment
3648	Lighting equipment, nec
3651	Household audio and video equipment
3691	Storage batteries
3694	Engine electrical equipment
3711	Motor vehicles and car bodies
3713	Truck and bus bodies
3714	Motor vehicle parts and accessories
3715	Truck trailers
Aerospace	
3544	Special dies, tools, jigs & fixtures
3545	Machine tool accessories
3721	Aircraft
3724	Aircraft engines and engine parts
3728	Aircraft parts and equipment, nec
3761	Guided missiles and space vehicles
3764	Space propulsion units and parts
3769	Space vehicle equipment, nec
Household appliances	
3632	Household refrigerators and freezers
3633	Household laundry equipment
3635	Household vacuum cleaners
3639	Household appliances, nec
3716	Motor homes
Communications services and software	
4899	Communications services, nec
7371	Computer programming services
7372	Prepackaged software
7373	Computer integrated systems design
7374	Data processing and preparation
7375	Information retrieval services
7379	Computer related services, nec
8711	Engineering services
8712	Architectural services
8713	Surveying services
8731	Commercial physical research
8732	Commercial nonphysical research
8734	Testing laboratories
Pharmaceuticals and medical technologies	
2833	Medicinals and botanicals
2834	Pharmaceutical preparations
2835	Diagnostic substances
2836	Biological products exc. diagnostic
3634	Electric housewares and fans
3841	Surgical and medical instruments
3842	Surgical appliances and supplies
8731	Commercial physical research
8732	Commercial nonphysical research
8734	Testing laboratories

Source: Factor analysis of input-output data; see Methods Appendix.

Appendix Table 5
Spatial concentration of value-chain employment in ARC MSAs
(1998, and growth 1989-1998)

ID		MSA name	Chemicals and plastics				Information technology				Industrial machinery			
			Cnty	Zips	LQ	Gro	Cnty	Zips	LQ	Gro	Cnty	Zips	LQ	Gro
4	I	Altoona, PA MSA												
5	I	Anniston, AL MSA												
6	I	Asheville, NC MSA		X	X				X			X	X	X
10	I	Binghamton, NY MSA		X	X			X	X		X	X	X	
11	I	Birmingham, AL MSA	X	X	X	X							X	
14	I	Charleston, WV MSA	X	X	X									
16	I	Chattanooga, TN-GA MSA		X	X				X					
21	I	Cumberland, MD-WV MSA												
22	I	Decatur, AL MSA		X	X		X							
23	I	Elmira, NY MSA						X			X		X	
24	I	Erie, PA MSA		X	X							X	X	
25	I	Florence, AL MSA			X									
26	I	Gadsden, AL MSA												
28	I	Greenville-Spartanburg-Anderson MSA	X	X	X			X			X	X	X	X
29	I	Hagerstown, MD PMSA										X		
33	I	Huntington-Ashland, WV-KY-OH MSA		X	X				X			X	X	
34	I	Huntsville, AL MSA		X			X	X	X					
35	I	Jamestown, NY MSA	X			X					X			
36	I	Johnson City-Kingsport-Bristol, TN-VA MSA	X	X	X							X	X	
37	I	Johnstown, PA MSA									X		X	
38	I	Knoxville, TN MSA			X								X	
47	I	Parkersburg-Marietta, WV-OH MSA	X	X	X									
48	I	Pittsburgh, PA MSA	X	X	X						X	X	X	
52	I	Scranton–Wilkes-Barre–Hazleton, PA MSA		X	X									
53	I	Sharon, PA MSA									X	X	X	
54	I	State College, PA MSA		X	X			X	X			X	X	
55	I	Steubenville-Weirton, OH-WV MSA												
60	I	Wheeling, WV-OH MSA		X	X									
61	I	Williamsport, PA MSA												
2	B	Albany-Schenectady-Troy, NY MSA		X	X		X	X		X	X	X	X	
3	B	Allentown-Bethlehem-Easton, PA MSA	X		X	X		X	X		X	X	X	
7	B	Athens, GA MSA		X	X						X		X	
8	B	Atlanta, GA MSA		X	X			X	X	X	X	X	X	X
13	B	Canton-Massillon, OH MSA	X		X	X					X	X	X	
17	B	Cincinnati, OH-KY-IN PMSA	X	X	X			X	X	X	X	X	X	
27	B	Greensboro, Winston-Salem, High Point MSA	X	X	X	X						X	X	
31	B	Harrisburg-Lebanon-Carlisle, PA MSA		X					X		X	X		
32	B	Hickory-Morganton-Lenoir, NC MSA		X	X									
39	B	Lexington, KY MSA			X			X	X			X	X	
43	B	Montgomery, AL MSA		X	X				X			X	X	
50	B	Roanoke, VA MSA		X	X				X			X	X	
57	B	Tuscaloosa, AL MSA	X			X								
59	B	Washington, DC-MD-VA-WV PMSA		X	X	X	X	X	X	X			X	X
62	B	Youngstown-Warren, OH MSA									X	X	X	
1	O	Akron, OH PMSA	X	X	X	X				X	X	X	X	
9	O	Auburn-Opelika, AL MSA												
12	O	Buffalo-Niagara Falls, NY MSA	X	X	X	X		X			X	X	X	
15	O	Charlotte-Gastonia-Rock Hill, NC-SC		X	X			X	X		X	X	X	
18	O	Cleveland-Lorain-Elyria, OH PMSA	X	X	X	X			X	X	X		X	
19	O	Columbus, GA-AL MSA		X	X									
20	O	Columbus, OH MSA		X	X	X		X	X			X	X	
30	O	Hamilton-Middleton, OH PMSA	X	X							X	X	X	
40	O	Lynchburg, VA MSA		X				X	X		X	X	X	
41	O	Mansfield, OH MSA									X	X	X	
42	O	Memphis, TN-AR-MS MSA	X	X	X							X	X	
44	O	Nashville, TN MSA		X	X	X			X			X	X	X
45	O	Newark, NJ PMSA	X	X	X	X			X	X		X	X	
46	O	Newburgh, NY-PA PMSA	X	X	X									
49	O	Reading, PA MSA	X			X							X	
51	O	Rochester, NY MSA		X	X	X		X	X	X	X		X	
56	O	Syracuse, NY MSA				X			X			X	X	
58	O	Utica-Rome, NY MSA		X	X				X			X	X	

Note: I: MSA entirely contained within the Appalachian region; B: MSA spans Appalachian border; O: MSA completely outside Appalachia, with borders at least 10 miles from region boundary.

Appendix Table 5 continues next page

Appendix Table 5 *continued*

Spatial concentration of value-chain employment in ARC MSAs

(1998, and growth 1989-1998)

			Motor vehicles				Aerospace				Household appliances			
ID		MSA name	Cnty	Zips	LQ	Gro	Cnty	Zips	LQ	Gro	Cnty	Zips	LQ	Gro
4	I	Altoona, PA MSA												
5	I	Anniston, AL MSA												
6	I	Asheville, NC MSA		X										
10	I	Binghamton, NY MSA		X										
11	I	Birmingham, AL MSA			X									
14	I	Charleston, WV MSA			X									
16	I	Chattanooga, TN-GA MSA			X									
21	I	Cumberland, MD-WV MSA							X					
22	I	Decatur, AL MSA		X							X	X	X	X
23	I	Elmira, NY MSA		X					X					
24	I	Erie, PA MSA							X					
25	I	Florence, AL MSA							X			X		
26	I	Gadsden, AL MSA							X					
28	I	Greenville-Spartanburg-Anderson MSA		X	X	X						X	X	
29	I	Hagerstown, MD PMSA		X	X									
33	I	Huntington-Ashland, WV-KY-OH MSA												
34	I	Huntsville, AL MSA		X	X			X	X			X		
35	I	Jamestown, NY MSA		X	X				X					
36	I	Johnson City-Kingsport-Bristol, TN-VA MSA		X	X	X			X		X	X	X	
37	I	Johnstown, PA MSA				X								
38	I	Knoxville, TN MSA		X	X				X					
47	I	Parkersburg-Marietta, WV-OH MSA												
48	I	Pittsburgh, PA MSA			X	X			X					
52	I	Scranton–Wilkes-Barre–Hazleton, PA MSA			X									
53	I	Sharon, PA MSA	X					X						
54	I	State College, PA MSA												
55	I	Steubenville-Weirton, OH-WV MSA												
60	I	Wheeling, WV-OH MSA												
61	I	Williamsport, PA MSA							X					
2	B	Albany-Schenectady-Troy, NY MSA								X				
3	B	Allentown-Bethlehem-Easton, PA MSA		X	X									
7	B	Athens, GA MSA												
8	B	Atlanta, GA MSA		X	X	X	X		X					
13	B	Canton-Massillon, OH MSA		X							X	X	X	
17	B	Cincinnati, OH-KY-IN PMSA	X	X	X	X	X	X	X				X	
27	B	Greensboro, Winston-Salem, High Point MSA		X	X	X								
31	B	Harrisburg-Lebanon-Carlisle, PA MSA		X										
32	B	Hickory-Morganton-Lenoir, NC MSA		X	X									
39	B	Lexington, KY MSA		X	X	X			X				X	
43	B	Montgomery, AL MSA			X				X		X	X	X	X
50	B	Roanoke, VA MSA												
57	B	Tuscaloosa, AL MSA		X	X									
59	B	Washington, DC-MD-VA-WV PMSA		X	X				X					
62	B	Youngstown-Warren, OH MSA	X	X	X	X			X		X			
1	O	Akron, OH PMSA	X	X	X			X	X		X	X	X	
9	O	Auburn-Opelika, AL MSA			X									
12	O	Buffalo-Niagara Falls, NY MSA	X	X	X									
15	O	Charlotte-Gastonia-Rock Hill, NC-SC		X	X	X								
18	O	Cleveland-Lorain-Elyria, OH PMSA	X	X	X				X		X	X		
19	O	Columbus, GA-AL MSA		X					X					
20	O	Columbus, OH MSA		X	X									
30	O	Hamilton-Middleton, OH PMSA	X				X	X	X					
40	O	Lynchburg, VA MSA												
41	O	Mansfield, OH MSA		X	X									
42	O	Memphis, TN-AR-MS MSA			X									
44	O	Nashville, TN MSA		X	X	X			X				X	
45	O	Newark, NJ PMSA		X										
46	O	Newburgh, NY-PA PMSA			X									
49	O	Reading, PA MSA		X	X									
51	O	Rochester, NY MSA	X	X	X									
56	O	Syracuse, NY MSA		X	X									
58	O	Utica-Rome, NY MSA												

Note: I: MSA entirely contained within the Appalachian region; B: MSA spans Appalachian border; O: MSA completely outside Appalachia, with borders at least 10 miles from region boundary.

Appendix Table 5 continues next page

Appendix Table 5 *continued*

Spatial concentration of value-chain employment in ARC MSAs

(1998, and growth 1989-1998)

ID		MSA name	Comm svcs, software				Pharm, med techs			
			Cnty	Zips	LQ	Gro	Cnty	Zips	LQ	Gro
4	I	Altoona, PA MSA								
5	I	Anniston, AL MSA								
6	I	Asheville, NC MSA								
10	I	Binghamton, NY MSA								
11	I	Birmingham, AL MSA			X					
14	I	Charleston, WV MSA			X					
16	I	Chattanooga, TN-GA MSA								
21	I	Cumberland, MD-WV MSA		X						
22	I	Decatur, AL MSA	X				X			
23	I	Elmira, NY MSA								
24	I	Erie, PA MSA						X		
25	I	Florence, AL MSA								
26	I	Gadsden, AL MSA							X	
28	I	Greenville-Spartanburg-Anderson MSA						X	X	
29	I	Hagerstown, MD PMSA								
33	I	Huntington-Ashland, WV-KY-OH MSA							X	
34	I	Huntsville, AL MSA	X	X	X		X	X	X	
35	I	Jamestown, NY MSA								
36	I	Johnson City-Kingsport-Bristol, TN-VA MSA						X	X	
37	I	Johnstown, PA MSA			X			X	X	
38	I	Knoxville, TN MSA		X	X			X	X	
47	I	Parkersburg-Marietta, WV-OH MSA								
48	I	Pittsburgh, PA MSA		X	X			X	X	
52	I	Scranton–Wilkes-Barre–Hazleton, PA MSA								
53	I	Sharon, PA MSA								
54	I	State College, PA MSA			X				X	
55	I	Steubenville-Weirton, OH-WV MSA								
60	I	Wheeling, WV-OH MSA								
61	I	Williamsport, PA MSA								
2	B	Albany-Schenectady-Troy, NY MSA	X	X	X	X	X	X	X	X
3	B	Allentown-Bethlehem-Easton, PA MSA					X			X
7	B	Athens, GA MSA								
8	B	Atlanta, GA MSA	X	X	X	X		X	X	
13	B	Canton-Massillon, OH MSA								
17	B	Cincinnati, OH-KY-IN PMSA		X	X	X	X	X	X	
27	B	Greensboro, Winston-Salem, High Point MSA						X	X	
31	B	Harrisburg-Lebanon-Carlisle, PA MSA		X	X				X	X
32	B	Hickory-Morganton-Lenoir, NC MSA						X		
39	B	Lexington, KY MSA							X	
43	B	Montgomery, AL MSA								
50	B	Roanoke, VA MSA								
57	B	Tuscaloosa, AL MSA								
59	B	Washington, DC-MD-VA-WV PMSA	X	X	X	X	X	X	X	X
62	B	Youngstown-Warren, OH MSA								
1	O	Akron, OH PMSA				X				X
9	O	Auburn-Opelika, AL MSA								
12	O	Buffalo-Niagara Falls, NY MSA							X	
15	O	Charlotte-Gastonia-Rock Hill, NC-SC		X	X	X			X	
18	O	Cleveland-Lorain-Elyria, OH PMSA				X		X	X	X
19	O	Columbus, GA-AL MSA		X	X					
20	O	Columbus, OH MSA	X	X	X	X		X	X	
30	O	Hamilton-Middleton, OH PMSA				X				
40	O	Lynchburg, VA MSA								
41	O	Mansfield, OH MSA								
42	O	Memphis, TN-AR-MS MSA								
44	O	Nashville, TN MSA			X			X	X	
45	O	Newark, NJ PMSA	X	X	X	X	X	X	X	X
46	O	Newburgh, NY-PA PMSA				X	X			
49	O	Reading, PA MSA				X	X	X	X	X
51	O	Rochester, NY MSA		X		X		X	X	
56	O	Syracuse, NY MSA						X	X	
58	O	Utica-Rome, NY MSA								

Note: I: MSA entirely contained within the Appalachian region; B: MSA spans Appalachian border; O: MSA completely outside Appalachia, with borders at least 10 miles from region boundary.

Appendix Table 6

Science and technology occupational classification

Aggregated Group	OES Code	OES Title	Defini-tion 1	Defini-tion 2
IT scientists, engineers and programmers	15-1011	Computer & Information Scientists, Research	X	X
	15-1021	Computer Programmers	X	X
	15-1031	Computer Software Engineers, Applications	X	X
	15-1032	Computer Software Engineers, Systems Software	X	X
	15-1041	Computer Support Specialists	X	
	15-1051	Computer Systems Analysts	X	
	15-1061	Database Administrators	X	
	15-1071	Network & Computer Systems Administrators	X	
	15-1081	Network Systems & Data Communications Analysts	X	
	17-2061	Computer Hardware Engineers	X	X
Mathematicians, statisticians, and physicists	15-2021	Mathematicians	X	X
	15-2031	Operations Research Analysts	X	X
	15-2041	Statisticians	X	X
	15-2091	Mathematical Techs	X	
	19-2012	Physicists	X	X
Agricultural scientists and engineers	17-2021	Agricultural Engineers	X	X
	19-1010	Agricultural & Food Scientists	X	X
	19-4011	Agricultural & Food Science Techs	X	
Biological scientists and technicians	19-1021	Biochemists & Biophysicists	X	X
	19-1022	Microbiologists	X	X
	19-4021	Biological Techs	X	
	19-1041	Epidemiologists	X	X
Chemists and chemical engineers	19-4031	Chemical Techs	X	
	17-2041	Chemical Engineers	X	X
	19-2031	Chemists	X	X
Environmental and resource scientists and technicians	19-2041	Environmental Scientists & Specialists, Incl. Health	X	X
	19-1023	Zoologists & Wildlife Biologists	X	X
	19-1031	Conservation Scientists	X	X
	19-4091	Environmental Science & Protection Techs, Incl. Health	X	
	19-4093	Forest & Conservation Techs	X	
	17-2081	Environmental Engineers	X	X
	17-3025	Environmental Engineering Techs	X	
Medical scientists and engineers	19-1042	Medical Scientists, Except Epidemiologists	X	X
	17-2031	Biomedical Engineers	X	X
	51-9082	Medical Appliance Techs	X	
Electrical engineers and technicians	17-2071	Electrical Engineers	X	X
	17-2072	Electronics Engineers, Except Computer	X	X
	17-3023	Electrical & Electronic Engineering Techs	X	
	17-3024	Electro-Mechanical Techs	X	
Materials engineers and scientists	17-2131	Materials Engineers	X	X
	19-2032	Materials Scientists	X	X
Aerospace engineers and technicians	19-2021	Atmospheric & Space Scientists	X	X
	17-2011	Aerospace Engineers	X	X
	17-3021	Aerospace Engineering & Operations Techs	X	
	49-2091	Avionics Techs	X	
Geoscientists and engineers	19-2043	Hydrologists	X	X
	19-4041	Geological & Petroleum Techs	X	
	19-2042	Geoscientists, Except Hydrologists & Geographers	X	X
	17-2171	Petroleum Engineers	X	X
	17-2151	Mining & Geological Engineers, Incl. Mining Safety Engineers	X	X
Nuclear engineers and technicians	19-4051	Nuclear Techs	X	
	17-2161	Nuclear Engineers	X	X
Industrial and mechanical engineers and technicians	17-2112	Industrial Engineers	X	X
	17-2141	Mechanical Engineers	X	X
	17-3026	Industrial Engineering Techs	X	
	17-3027	Mechanical Engineering Techs	X	

Source: Selected from 709 total occupations included in 1999 Occupational Employment Statistics data (U.S. Bureau of Labor Statistics). Definition 1 includes all occupations; Definition 2 excludes technicians.

Appendix Table 7

Location quotients: Scientists and engineers, 1999

Employment location quotients for scientists and engineers only

ID		MSA	IT	Math	AgSci	Bio	Chem	Enviro	Med	Elect	Matrl	Aero	Geo	Nucl	Indust
4	I	Altoona, PA	0.4												0.5
5	I	Anniston, AL								0.4					0.3
6	I	Asheville, NC	0.1					1.0		0.3					0.4
11	I	Binghamton, NY	1.5							2.5					1.1
12	I	Birmingham, AL	0.9	0.3			0.3	0.6		0.3	1.6		0.2		0.9
15	I	Charleston, WV	0.5				1.3								
17	I	Chattanooga, TN-GA	0.4					0.3		0.1					0.8
22	I	Cumberland, MD-WV													
23	I	Decatur, AL	0.1				1.5								0.8
24	I	Elmira, NY	0.1												0.9
25	I	Erie, PA	0.3								1.8				1.0
26	I	Florence, AL								0.6					0.8
27	I	Gadsden, AL													
29	I	Greenville-Spartanburg-Anderson, SC	0.4	0.3			1.7	0.3		0.7					1.5
30	I	Hagerstown, MD	0.1												
34	I	Huntington-Ashland, WV-KY-OH	0.1				0.6			0.2					0.1
35	I	Huntsville, AL	1.8				0.6	0.5		4.3		32.8			3.1
36	I	Jamestown, NY													0.6
37	I	Johnson City-Kingsport-Bristol, TN-VA	0.2					0.5							0.4
38	I	Johnstown, PA	0.0												0.2
39	I	Knoxville, TN	0.3					1.0		0.6			0.4		0.6
48	I	Parkersburg-Marietta, WV-OH						0.5							0.8
49	I	Pittsburgh, PA	0.7	1.2	0.3		0.3	0.5		0.8	2.6		0.2		0.9
53	I	Scranton–Wilkes-Barre–Hazleton, PA	0.5				0.1			0.3					0.6
54	I	Sharon, PA													0.4
55	I	State College, PA								0.9					0.3
56	I	Steubenville-Weirton, OH-WV								0.6					
61	I	Wheeling, WV-OH													
62	I	Williamsport, PA	0.1												
2	B	Albany-Schenectady-Troy, NY	0.3					1.3			0.4		0.3		0.1
3	B	Allentown-Bethlehem-Easton, PA	0.4	0.2			2.3			0.4	1.0				0.8
7	B	Athens, GA	0.1							0.8					0.6
8	B	Atlanta, GA	1.7	1.3		1.2	1.0	1.4	0.6	1.4	0.4		0.3		0.8
14	B	Canton-Massillon, OH	0.0							0.2					1.1
18	B	Cincinnati, OH-KY-IN	0.9			0.9	1.3	0.7		0.5	1.0				1.2
28	B	Greensboro–Winston-Salem–High Point, NC	0.8	0.1			1.0	0.0		1.3	2.8				0.8
32	B	Harrisburg-Lebanon-Carlisle, PA	0.5	0.2				0.5		0.3	0.4				0.8
33	B	Hickory-Morganton-Lenoir, NC	0.2				0.4				0.7				0.6
40	B	Lexington, KY	0.4				0.4	0.3		0.5			0.4		1.0
44	B	Montgomery, AL	0.5	0.5											0.1
51	B	Roanoke, VA	0.8	0.5						0.8					0.7
58	B	Tuscaloosa, AL													0.2
60	B	Washington, DC-MD-VA-WV	2.2	4.9	1.3	2.4	0.2	1.8	3.2	2.3	0.5	1.8	1.1		0.8
64	B	Youngstown-Warren, OH	0.2				0.2	0.3		0.2	2.8				0.9

Appendix Table 7 continues next page

Appendix Table 7 *continued*

Location quotients: Scientists and engineers, 1999

Employment location quotients for scientists and engineers only

ID		MSA	IT	Math	AgSci	Bio	Chem	Enviro	Med	Elect	Matrl	Aero	Geo	Nucl	Indust
1	O	Akron, OH	0.5				1.2	0.1		0.9					1.4
9	O	Auburn-Opelika, AL													
10	O	Baltimore, MD	0.7	1.4	0.4	1.2	0.6	0.6	1.2	0.8	0.8		0.2		1.1
13	O	Buffalo-Niagara Falls, NY	0.5				1.2			0.4	1.2				1.0
16	O	Charlotte-Gastonia-Rock Hill, NC-SC	1.0	0.5			0.8	0.6		0.6				2.8	1.0
19	O	Cleveland-Lorain-Elyria, OH	0.6	0.1			1.8	0.6	0.3	1.3	1.4				1.8
20	O	Columbus, GA-AL	0.1												0.2
21	O	Columbus, OH	1.6	0.5			0.8	0.7	0.2	0.9	0.3				1.0
31	O	Hamilton-Middletown, OH	0.5				0.4			0.8					0.4
41	O	Lynchburg, VA	0.2							0.2					
42	O	Mansfield, OH	0.1							0.9					2.0
43	O	Memphis, TN-AR-MS	0.3	0.9			0.9	0.4	0.4	0.3	0.2		0.3		0.5
45	O	Nashville, TN	0.5		0.6	2.3	0.3	2.0		0.3	0.2	0.1			0.4
46	O	Newark, NJ	1.4				4.7	1.5		1.1	0.5				0.9
47	O	Newburgh, NY-PA						0.6							0.3
50	O	Reading, PA	0.0				1.1			0.8	1.6				0.9
52	O	Rochester, NY	0.6				1.4	0.1		0.4	2.0				1.8
57	O	Syracuse, NY	0.6				0.1	1.1		1.0	0.7				1.1
59	O	Utica-Rome, NY	0.4	0.5						0.3					0.3
63	O	York, PA	0.1				0.2			0.3	0.8				2.1

Source: Occupational Employment Statistics, U.S. Bureau of Labor Statistics. I: MSA entirely contained within the Appalachian region; B: MSA spans Appalachian border; O: MSA completely outside Appalachia, with borders at least 10 miles from region boundary. N/A: Missing. Blank: No estimate available (see text for explanation). Values > 1.2 shaded.

Appendix Table 8

Location quotients: Location quotients: Technicians, 1999

Employment location quotients for technicians only

ID		MSA	IT	Math	AgSci	Bio	Chem	Enviro	Med	Elect	Matrl	Aero	Geo	Nucl	Indust
4	I	Altoona, PA	0.7												
5	I	Anniston, AL													
6	I	Asheville, NC	0.5							0.8					0.3
11	I	Binghamton, NY	0.7							0.4					
12	I	Birmingham, AL	1.3				0.2		8.1	1.2					0.5
15	I	Charleston, WV	0.0							0.5					
17	I	Chattanooga, TN-GA	0.3				0.3			0.6					0.3
22	I	Cumberland, MD-WV													
23	I	Decatur, AL	0.1				2.9			0.6					
24	I	Elmira, NY	0.1							0.3					0.9
25	I	Erie, PA	0.3				1.8			0.5					
26	I	Florence, AL	0.2				1.0								
27	I	Gadsden, AL	0.1												
29	I	Greenville-Spartanburg-Anderson, SC	0.5				2.5	0.3		1.3					1.2
30	I	Hagerstown, MD	0.1							0.7					
34	I	Huntington-Ashland, WV-KY-OH	0.3				1.7			0.4					
35	I	Huntsville, AL	1.6							2.5					1.6
36	I	Jamestown, NY	0.1												
37	I	Johnson City-Kingsport-Bristol, TN-VA	0.3							0.5					
38	I	Johnstown, PA	0.1							0.2					
39	I	Knoxville, TN	0.5				1.0			1.2					0.8
48	I	Parkersburg-Marietta, WV-OH	0.0							0.7					
49	I	Pittsburgh, PA	1.0		0.6			0.2		0.8					1.1
53	I	Scranton–Wilkes-Barre–Hazleton, PA	0.5				0.7	0.2		1.0					0.3
54	I	Sharon, PA													
55	I	State College, PA	0.2							2.1					
56	I	Steubenville-Weirton, OH-WV	0.1				1.1			0.6					
61	I	Wheeling, WV-OH	0.2												
62	I	Williamsport, PA	0.2							1.1					
2	B	Albany-Schenectady-Troy, NY	1.2							0.3					
3	B	Allentown-Bethlehem-Easton, PA	0.8				2.5	0.4		0.6					0.3
7	B	Athens, GA	0.1				0.8			0.3					
8	B	Atlanta, GA	1.7		0.5	0.3	0.8	0.2		0.8		0.7			1.1
14	B	Canton-Massillon, OH	0.5							0.3					0.3
18	B	Cincinnati, OH-KY-IN	1.0		0.4		0.9	1.4		0.5					0.3
28	B	Greensboro–Winston-Salem–High Point, NC	0.7			0.2	0.8	0.4		1.0					0.6
32	B	Harrisburg-Lebanon-Carlisle, PA	1.5		0.7			0.8		0.7					0.4
33	B	Hickory-Morganton-Lenoir, NC	0.3				1.0	0.6		0.4					0.4
40	B	Lexington, KY	0.8					0.6		0.3					
44	B	Montgomery, AL	1.1							0.5					
51	B	Roanoke, VA	0.8				0.9	0.9		0.8					1.3
58	B	Tuscaloosa, AL	0.0												
60	B	Washington, DC-MD-VA-WV	2.6	3.4		2.8	0.0	0.8		0.9		0.6			0.7
64	B	Youngstown-Warren, OH	0.2												0.8

Appendix Table 8 continues next page

Appendix Table 8 *continued*

Location quotients: Location quotients: Technicians, 1999

Employment location quotients for technicians only

ID		MSA	IT	Math	AgSci	Bio	Chem	Enviro	Med	Elect	Matrl	Aero	Geo	Nucl	Indust
1	O	Akron, OH	0.7				1.6	0.3							0.5
9	O	Auburn-Opelika, AL													
10	O	Baltimore, MD	1.1				0.7		0.9	0.5					1.2
13	O	Buffalo-Niagara Falls, NY	0.5				1.2	0.5		0.5					1.1
16	O	Charlotte-Gastonia-Rock Hill, NC-SC	1.2				1.1	0.8	0.4	1.0		0.6			1.6
19	O	Cleveland-Lorain-Elyria, OH	1.1				1.0	0.4		0.9					1.5
20	O	Columbus, GA-AL	0.5				2.1			0.3					
21	O	Columbus, OH	1.3				1.0			0.4					0.1
31	O	Hamilton-Middletown, OH	0.4				1.3								
41	O	Lynchburg, VA	0.6							0.7					
42	O	Mansfield, OH	0.3							0.6					
43	O	Memphis, TN-AR-MS	0.9			0.3	1.7	0.4		0.6					0.9
45	O	Nashville, TN	0.7			0.3		0.2		1.1		0.5			0.7
46	O	Newark, NJ	0.6				5.2			0.6					0.8
47	O	Newburgh, NY-PA	0.4				2.6			0.4					
50	O	Reading, PA	0.2				2.5	0.8		1.4					
52	O	Rochester, NY	1.1			0.2		0.4							1.7
57	O	Syracuse, NY	1.1					0.6		0.6					1.4
59	O	Utica-Rome, NY	0.3							0.8					
63	O	York, PA	0.3					0.4		0.6					0.6

Source: Occupational Employment Statistics, U.S. Bureau of Labor Statistics. I: MSA entirely contained within the Appalachian region; B: MSA spans Appalachian border; O: MSA completely outside Appalachia, with borders at least 10 miles from region boundary. N/A: Missing. Blank: No estimate available (see text for explanation). Values > 1.2 shaded.

Appendix Table 9

Concordance: Patents to technology groups

Product Field	SIC	Chemicals and plastics	Information technology	Instruments	Industrial machinery	Motor vehicles	Aerospace	Household appliances	Pharmaceuticals	Pharma+K25 + med techs	Metals	Other
Food & kindred products	20											X
Textile mill products	22											X
Industrial inorganic chemistry	281	X										
Industrial organic chemistry	286	X										
Plastics materials & synthetic resins	282	X										
Agricultural chemicals	287	X										
Soaps, detergents, cleaners, perfumes, cosmetics & toiletries	284	X										
Paints, varnishes, lacquers, enamels, & allied products	285	X				X						
Miscellaneous chemical products	289	X										
Drugs & medicines	283								X	X		
Petroleum & natural gas extraction & refining	13, 29	X										
Rubber & miscellaneous plastics products	30	X										
Stone, clay, glass & concrete products	32											X
Primary ferrous products	A*										X	
Primary & secondary non-ferrous metals	B*										X	
Fabricated metal products	C*										X	
Engines & turbines	351				X	X						
Farm & garden machinery & equipment	352				X							
Construction, mining & material handling machinery & equipment	353				X	X						
Metal working machinery & equipment	354				X		X					
Office computing & accounting machines	357		X									
Special industry machinery, except metal working	355				X							
General industrial machinery & equipment	356				X							
Refrigeration & service industry machinery	358				X							
Miscellaneous machinery, except electrical	359				X							
Electrical transmission & distribution equipment	361, 3825		X									
Electrical industrial apparatus	362		X		X							
Household appliances	363							X		X		
Electrical lighting & wiring equipment	364					X						
Miscellaneous electrical machinery, equipment & supplies	369		X			X						
Radio & television receiving equipment except communication types	365		X			X						
Electronic components & accessories & communications equipment	366-367		X									
Motor vehicles & other motor vehicle equipment	371					X						
Guided missiles & space vehicles & parts	376						X					
Ship & boat building & repairing	373					X						
Railroad equipment	374					X						
Motorcycles, bicycles, & parts	375					X						
Miscellaneous transportation equipment	D*					X						
Ordinance except missiles	348, 3795	X										
Aircraft & parts	372						X					
Professional & scientific instruments	E*			X						X		
All other SIC's	99											X

* Note; patent to SIC assignment is from the US PTO based on the 1972 Standard Industrial Classifications. A: SICs 331, 332, 3399, 3462; B: SICs 333-336, 339 (ex. 3399), 3463; C: SICs 34 (ex. 3462, 3463, 348); D: SICs 379 (except 3795); E: SICs 38 (except 3825).

Appendix Table 10

Spatial concentration of patenting activity by technology area, (1990-1999)

ID		MSA name	Chemicals, plastics		Information technology		Instruments		Industrial machinery		Motor vehicles	
			Cnty	LQ	Cnty	LQ	Cnty	LQ	Cnty	LQ	Cnty	LQ
4	I	Altoona, PA MSA								X		
5	I	Anniston, AL MSA										
6	I	Asheville, NC MSA		X						X		
10	I	Binghamton, NY MSA			X	X			X			
11	I	Birmingham, AL MSA			X							
14	I	Charleston, WV MSA		X								
16	I	Chattanooga, TN-GA MSA								X		X
21	I	Cumberland, MD-WV MSA										
22	I	Decatur, AL MSA										
23	I	Elmira, NY MSA										
24	I	Erie, PA MSA								X		X
25	I	Florence, AL MSA		X								
26	I	Gadsden, AL MSA										
28	I	Greenville-Spartanburg-Anderson MSA		X					X	X		X
29	I	Hagerstown, MD PMSA										
33	I	Huntington-Ashland, WV-KY-OH MSA										
34	I	Huntsville, AL MSA				X		X				
35	I	Jamestown, NY MSA							X			
36	I	Johnson City-Kingsport-Bristol, TN-VA MSA		X								X
37	I	Johnstown, PA MSA										
38	I	Knoxville, TN MSA						X		X		
47	I	Parkersburg-Marietta, WV-OH MSA		X								X
48	I	Pittsburgh, PA MSA				X			X	X		X
52	I	Scranton–Wilkes-Barre–Hazleton, PA MSA								X		X
53	I	Sharon, PA MSA										
54	I	State College, PA MSA										
55	I	Steubenville-Weirton, OH-WV MSA										
60	I	Wheeling, WV-OH MSA		X								
61	I	Williamsport, PA MSA								X		X
2	B	Albany-Schenectady-Troy, NY MSA	X	X	X	X			X	X	X	X
3	B	Allentown-Bethlehem-Easton, PA MSA	X	X	X	X			X		X	
7	B	Athens, GA MSA		X								
8	B	Atlanta, GA MSA		X		X				X		X
13	B	Canton-Massillon, OH MSA							X	X	X	X
17	B	Cincinnati, OH-KY-IN PMSA	X	X				X	X	X	X	X
27	B	Greensboro, Winston-Salem, High Point MSA								X		
31	B	Harrisburg-Lebanon-Carlisle, PA MSA				X				X		
32	B	Hickory-Morganton-Lenoir, NC MSA										
39	B	Lexington, KY MSA				X						
43	B	Montgomery, AL MSA								X		
50	B	Roanoke, VA MSA				X		X		X		X
57	B	Tuscaloosa, AL MSA										
59	B	Washington, DC-MD-VA-WV PMSA	X		X	X		X				
62	B	Youngstown-Warren, OH MSA				X				X		
1	O	Akron, OH PMSA	X	X					X	X	X	X
9	O	Auburn-Opelika, AL MSA		X								
12	O	Buffalo-Niagara Falls, NY MSA							X	X		
15	O	Charlotte-Gastonia-Rock Hill, NC-SC		X						X		X
18	O	Cleveland-Lorain-Elyria, OH PMSA		X					X	X	X	X
19	O	Columbus, GA-AL MSA										
20	O	Columbus, OH MSA		X								
30	O	Hamilton-Middleton, OH PMSA	X	X					X	X	X	X
40	O	Lynchburg, VA MSA				X				X		X
41	O	Mansfield, OH MSA								X		
42	O	Memphis, TN-AR-MS MSA						X				
44	O	Nashville, TN MSA						X		X		
45	O	Newark, NJ PMSA										
46	O	Newburgh, NY-PA PMSA	X	X	X				X		X	
49	O	Reading, PA MSA	X		X				X		X	
51	O	Rochester, NY MSA	X		X	X	X	X	X	X	X	
56	O	Syracuse, NY MSA				X			X	X	X	X
58	O	Utica-Rome, NY MSA						X				

Note: I: MSA entirely contained within the Appalachian region; B: MSA spans Appalachian border; O: MSA completely outside Appalachia but adjacent to region.

Appendix Table 10 continues next page

Appendix Table 10 *continued*

Spatial concentration of patenting activity by technology area, (1990-1999)

			Aerospace		Household appliances		Pharma ceuticals		Metals		Other	
ID		MSA name	Cnty	LQ	Cnty	LQ	Cnty	LQ	Cnty	LQ	Cnty	LQ
4	I	Altoona, PA MSA										
5	I	Anniston, AL MSA										
6	I	Asheville, NC MSA										X
10	I	Binghamton, NY MSA	X									
11	I	Birmingham, AL MSA						X				
14	I	Charleston, WV MSA										
16	I	Chattanooga, TN-GA MSA								X		X
21	I	Cumberland, MD-WV MSA										
22	I	Decatur, AL MSA										
23	I	Elmira, NY MSA		X						X	X	X
24	I	Erie, PA MSA		X						X		
25	I	Florence, AL MSA										
26	I	Gadsden, AL MSA										
28	I	Greenville-Spartanburg-Anderson MSA	X	X							X	X
29	I	Hagerstown, MD PMSA										
33	I	Huntington-Ashland, WV-KY-OH MSA										
34	I	Huntsville, AL MSA										
35	I	Jamestown, NY MSA							X			
36	I	Johnson City-Kingsport-Bristol, TN-VA MSA										
37	I	Johnstown, PA MSA							X			
38	I	Knoxville, TN MSA										
47	I	Parkersburg-Marietta, WV-OH MSA										
48	I	Pittsburgh, PA MSA	X	X					X	X		X
52	I	Scranton–Wilkes-Barre–Hazleton, PA MSA										X
53	I	Sharon, PA MSA								X		
54	I	State College, PA MSA										
55	I	Steubenville-Weirton, OH-WV MSA								X		
60	I	Wheeling, WV-OH MSA										
61	I	Williamsport, PA MSA								X		
2	B	Albany-Schenectady-Troy, NY MSA	X	X	X	X		X	X		X	
3	B	Allentown-Bethlehem-Easton, PA MSA			X		X		X	X	X	
7	B	Athens, GA MSA						X				
8	B	Atlanta, GA MSA			X	X			X	X	X	X
13	B	Canton-Massillon, OH MSA	X	X					X	X		
17	B	Cincinnati, OH-KY-IN PMSA	X		X		X	X	X		X	
27	B	Greensboro, Winston-Salem, High Point MSA										X
31	B	Harrisburg-Lebanon-Carlisle, PA MSA	X	X								
32	B	Hickory-Morganton-Lenoir, NC MSA								X		
39	B	Lexington, KY MSA										
43	B	Montgomery, AL MSA										
50	B	Roanoke, VA MSA										
57	B	Tuscaloosa, AL MSA										
59	B	Washington, DC-MD-VA-WV PMSA					X	X		X		X
62	B	Youngstown-Warren, OH MSA								X		
1	O	Akron, OH PMSA	X	X	X				X		X	
9	O	Auburn-Opelika, AL MSA										
12	O	Buffalo-Niagara Falls, NY MSA			X	X			X	X		X
15	O	Charlotte-Gastonia-Rock Hill, NC-SC			X					X		X
18	O	Cleveland-Lorain-Elyria, OH PMSA	X		X				X	X	X	X
19	O	Columbus, GA-AL MSA										
20	O	Columbus, OH MSA			X					X		X
30	O	Hamilton-Middleton, OH PMSA	X	X	X		X	X	X		X	X
40	O	Lynchburg, VA MSA										
41	O	Mansfield, OH MSA										
42	O	Memphis, TN-AR-MS MSA						X				
44	O	Nashville, TN MSA						X		X		X
45	O	Newark, NJ PMSA										
46	O	Newburgh, NY-PA PMSA			X		X		X		X	X
49	O	Reading, PA MSA					X		X	X	X	
51	O	Rochester, NY MSA	X		X				X		X	
56	O	Syracuse, NY MSA		X	X	X				X		
58	O	Utica-Rome, NY MSA										

Note: I: MSA entirely contained within the Appalachian region; B: MSA spans Appalachian border; O: MSA completely outside Appalachia but adjacent to region.

Appendix Table 11

SBIR/STTR/ATP award winners in ARC region, FY 2000

Company Name	City	St.	Type	Amount	Technology
TENSION SYSTEMS L.L.C.	Madison	AL	SBIR		Aerospace
ADVANCED OPTICAL SYSTEMS, INC.	Huntsville	AL	SBIR		Aerospace
CFD Research Corp.	Huntsville	AL	SBIR		Aerospace
EAST WEST ENTERPRISES INC.	Huntsville	AL	SBIR		Aerospace
EAST WEST ENTERPRISES INC.	Huntsville	AL	SBIR		Aerospace
EAST WEST ENTERPRISES, INC.	Huntsville	AL	SBIR		Aerospace
GOMEZ RESEARCH ASSOC., INC.	Huntsville	AL	SBIR		Aerospace
SIMULATION TECHNOLOGIES, INC.	Huntsville	AL	SBIR		Aerospace
Aegis Technologies Group, Inc.	Huntsville	AL	SBIR		Aerospace
Aegis Technologies Group, Inc.	Huntsville	AL	SBIR		Aerospace
PLASMA PROCESSES, INC.	Huntsville	AL	SBIR		Aerospace
NEOTERIC TECHNOLOGIES, INC.	Huntsville	AL	SBIR		Aerospace
AI Signal Research, Inc.	Huntsville	AL	SBIR		Aerospace
Jaycor, Inc.	Huntsville	AL	SBIR		Aerospace
SRS Technologies	Huntsville	AL	SBIR		Aerospace
CUSTOM ANALYTICAL ENGINEERING SYSTEM	Flintstone	MD	SBIR		Aerospace
Odyssey Research Associates, Inc.	Ithaca	NY	SBIR		Aerospace
LANCORP Advanced Systems, Inc.	Imperial	PA	SBIR	$68,769	Aerospace
NANOMAT, INC.	Somerset	PA	SBIR		Aerospace
COMBUSTION PROPULSION & BALLISTIC	State College	PA	SBIR		Aerospace
PRESCHUTTI & ASSOC., INC.	State College	PA	SBIR		Aerospace
TRS Ceramics, Inc.	State College	PA	SBIR		Aerospace
TRS Ceramics, Inc.	State College	PA	SBIR		Aerospace
HVS TECHNOLOGIES, INC.	STATE COLLEGE	PA	SBIR		Aerospace
LYTEC LLC	TULLAHOMA	TN	SBIR		Aerospace
Accurate Automation Corp.	Chattanooga	TN	SBIR		Aerospace
Accurate Automation Corp.	Chattanooga	TN	SBIR		Aerospace
Luna Innovations, Inc.	Blacksburg	VA	SBIR		Aerospace
NanoSonic, Inc.	Christiansburg	VA	SBIR		Aerospace
F&S, Inc.	Blacksburg	VA	SBIR		Aerospace
Information Systems Laboratories, Inc.	Huntsville	AL	STTR		Aerospace
Accurate Automation Corp.	Chattanooga	TN	STTR		Aerospace
Luna Innovations, Inc.	Blacksburg	VA	SBIR		Aerospace, Industrial Machinery
Technology in Blacksburg, Inc.	Blacksburg	VA	SBIR		Aerospace, Industrial Machinery
Innovative Dynamics, Inc.	Ithaca	NY	SBIR		Aerospace, Motor Vehicles
AZ TECHNOLOGY	Huntsville	AL	SBIR		Chemicals
Physitron, Inc.	Huntsville	AL	SBIR		Chemicals
CAT Flight Services, Inc.	Huntsville	AL	SBIR		Chemicals
Super-Pulse	Ithaca	NY	SBIR	$100,000	Chemicals
E. H. Hall/Westfield Tanning Company	Westfield	PA	SBIR	$58,694/6 Months	Chemicals
EXPORTech Company Inc	New Kensington	PA	SBIR	$400,000	Chemicals
EXPORTech Company Inc	New Kensington	PA	SBIR	$96,202	Chemicals
EXPORTech Company, Inc.	New Kensington	PA	SBIR		Chemicals
Media and Process Technology, Inc.	Pittsburgh	PA	SBIR		Chemicals
Nanomat, Inc.	North Huntingdon	PA	SBIR		Chemicals
SURFACE TREATMENT TECHNOLOGIES, INC.	Tullahoma	TN	SBIR		Chemicals
White Cliff Biosystems Co.	Kingsport	TN	SBIR		Chemicals
ATMOSPHERIC GLOW TECHNOLOGIES	Rockford	TN	SBIR		Chemicals
PETNet Pharmaceutical Services, Inc.	Knoxville	TN	SBIR		Chemicals
Cryogenic Applications F, Inc.	Clinton	TN	SBIR		Chemicals
Luna Innovations, Inc.	Blacksburg	VA	SBIR		Chemicals
NanoSonic, Inc.	Christiansburg	VA	SBIR		Chemicals
NanoSonic, Inc.	Christiansburg	VA	SBIR		Chemicals
HY-Tech Research Corp	Radford	VA	SBIR	$399,996	Chemicals
Luna Innovations, Inc.	Blacksburg	VA	SBIR		Chemicals
F&S, Inc./Luna Innovations, Inc.	Blacksburg	VA	SBIR	$69,974	Chemicals

Appendix Table 11 continues next page

Appendix Table 11 *continued*

SBIR/STTR/ATP award winners in ARC region, FY 2000

Company Name	City	St.	Type	Amount	Technology
TOUCHSTONE RESEARCH LABORATORY, LTD.	Triadelphia	WV	SBIR		Chemicals
RJ Lee Group, Incorporated	Monroeville	PA	STTR		Chemicals
SDR Plastics, Inc.	Ravenswood	WV	STTR		Chemicals
Time Domain Corporation	Huntsville	AL	ATP	$6,801,000	Communications services, software
Medical Archival Systems Incorporated	Pittsburgh	PA	ATP	$3,535,000	Communications services, software
CompAS Controls Inc.	Indiana	PA	ATP	$5,706,000	Communications services, software
Pennsylvania State University	University Park	PA	ATP		Communications services, software
Engineering Sciences Inc	Huntsville	AL	SBIR	$100,000	Communications services, software
CFD Research Corp.	Huntsville	AL	SBIR		Communications services, software
CFD Research Corp.	Huntsville	AL	SBIR	$399,985	Communications services, software
CFD Research Corp.	Huntsville	AL	SBIR	$399,946	Communications services, software
CFD Research Corp.	Huntsville	AL	SBIR	$99,984	Communications services, software
CFD Research Corp.	Huntsville	AL	SBIR	$99,947	Communications services, software
OPTICAL SCIENCES CORP.	Huntsville	AL	SBIR		Communications services, software
FlowLynx, Inc.	Huntsville	AL	SBIR		Communications services, software
Physitron, Inc.	Huntsville	AL	SBIR	$50,000	Communications services, software
AZ Technology, Inc.	Huntsville	AL	SBIR		Communications services, software
Earth Mapping International, Inc.	Gainesville	GA	SBIR	$99,996	Communications services, software
SEARCH TECHNOLOGY, INC.	Norcross	GA	SBIR		Communications services, software
MPI Software Technology, Inc.	Starkville	MS	SBIR	$75,000	Communications services, software
MPI SOFTWARE TECHNOLOGY, INC.	Starkville	MS	SBIR		Communications services, software
MPI Software Technology	Starkville	MS	SBIR	$400,000	Communications services, software
MPI Software Technology	Starkville	MS	SBIR	$400,000	Communications services, software
WETSTONE TECHNOLOGIES, INC.	Freeville	NY	SBIR		Communications services, software
3DVIS TECHNOLOGIES, INC.	Vestal	NY	SBIR		Communications services, software
DIAMOND VISIONICS LLC	Vestal	NY	SBIR		Communications services, software
Munex, Inc.	Ithaca	NY	SBIR	$69,011/6 Months	Communications services, software
Odyssey Research Associates, Inc.	Ithaca	NY	SBIR		Communications services, software
MAYA Design Group, Inc.	Pittsburgh	PA	SBIR		Communications services, software
TerraSim, Inc.	Pittsburgh	PA	SBIR		Communications services, software
Quantum Simulations, Inc.	Murrysville	PA	SBIR	$50,000	Communications services, software
Discovery Machine, Inc.	Montgomery	PA	SBIR		Communications services, software
Platform Digital, LLC	Pittsburgh	PA	SBIR		Communications services, software
Psychology Software Tools	Pittsburgh	PA	SBIR	$99,558	Communications services, software
TELE-TRACKING TECHNOLOGIES	PITTSBURGH	PA	SBIR	$100,000	Communications services, software
Q-CHEM, INC.	EXPORT	PA	SBIR	$551,979	Communications services, software
QSI	Murrysville	PA	SBIR	$100,000	Communications services, software
Accurate Automation Corp	Chattanooga	TN	SBIR	$399,999	Communications services, software
Genome Informatics Corporation	Oak Ridge	TN	SBIR		Communications services, software
IntraSpec, Inc.	Oak Ridge	TN	SBIR		Communications services, software
American Research Corporation of Virginia	Radford	VA	SBIR	$50,000	Communications services, software
D.N. American, Inc.	Fairmont	WV	SBIR		Communications services, software
Kraus Communication LLC	Fairmont	WV	SBIR	$299,974	Communications services, software
GrammaTech, Inc.	Ithaca	NY	STTR		Communications services, software
Torrington Company	Norcross	GA	ATP		Industrial Machinery
Hardinge, Inc.	Elmira	NY	ATP	$11,747,000	Industrial Machinery
Carnegie-Mellon University	Pittsburgh	PA	ATP	$13,720,000	Industrial Machinery
Kennametal	Latrobe	PA	ATP		Industrial Machinery
Aegis Technologies Group, Inc.	Huntsville	AL	SBIR		Industrial Machinery
CFD Research Corp.	Huntsville	AL	SBIR		Industrial Machinery
SRS Technologies	Huntsville	AL	SBIR		Industrial Machinery
Plasma Processes, Inc.	Huntsville	AL	SBIR		Industrial Machinery
Thortek	Irvine	KY	SBIR		Industrial Machinery
Global Aircraft Corp.	Starkville	MS	SBIR	$100,000	Industrial Machinery
AGILE SYSTEMS, INC.	Bethel	OH	SBIR		Industrial Machinery
LANCORP Advanced Engineering & Syst	Pittsburgh	PA	SBIR		Industrial Machinery

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Appendix Table 11 *continued*

SBIR/STTR/ATP award winners in ARC region, FY 2000

Company Name	City	St.	Type	Amount	Technology
Surface Treatment Technologies, Inc.	Tullahoma	TN	SBIR		Industrial Machinery
VPT, Inc.	Blacksburg	VA	SBIR		Industrial Machinery
NanoSonic, Inc.	Christiansburg	VA	SBIR		Industrial Machinery
NanoSonic, Inc.	Christiansburg	VA	SBIR	$399,800	Industrial Machinery
Rainbow Displays, Inc.	Endicott	NY	ATP	$4,568,000	IT and instruments
CFD Research Corp.	Huntsville	AL	SBIR		IT and instruments
CFD Research Corp.	Huntsville	AL	SBIR		IT and instruments
CFD Research Corp.	Huntsville	AL	SBIR		IT and instruments
Morgan Research Corporation	Huntsville	AL	SBIR		IT and instruments
Physitron	Huntsville	AL	SBIR	$100,000	IT and instruments
Aegis Technologies Group, Inc.	Huntsville	AL	SBIR		IT and instruments
United Applied Technologies, Inc.	Huntsville	AL	SBIR		IT and instruments
United Applied Technologies, Inc.	Huntsville	AL	SBIR		IT and instruments
Alabama Cryogenic Engineering, Inc.	Huntsville	AL	SBIR		IT and instruments
AI Signal Research, Inc.	Huntsville	AL	SBIR		IT and instruments
Photon-X, Inc.	Huntsville	AL	SBIR		IT and instruments
Search Technology, Inc.	Norcross	GA	SBIR		IT and instruments
GESAC, Inc.	Boonsboro	MD	SBIR	$97,897	IT and instruments
Applied Pulsed Power, Inc.	Ithaca	NY	SBIR		IT and instruments
Sunpower, Inc.	Athens	OH	SBIR		IT and instruments
ChemIcon Inc.	Pittsburgh	PA	SBIR		IT and instruments
TRS CERAMICS, INC.	STATE COLLEGE	PA	SBIR	$98,942	IT and instruments
Atolytics, Inc.	State College	PA	SBIR	$300,000	IT and instruments
Licom Technologies, Inc.	State College	PA	SBIR		IT and instruments
Licom Technologies, Inc.	State College	PA	SBIR		IT and instruments
SPECTRUMEDIX CORPORATION	STATE COLLEGE	PA	SBIR	$374,937	IT and instruments
LANCORP Advanced Engineering & Syst	Pittsburgh	PA	SBIR		IT and instruments
Nuclear Safeguards and Security Systems, LLC	Clinton	TN	SBIR		IT and instruments
CRYOMAGNETICS, INC.	OAK RIDGE	TN	SBIR	$152,260	IT and instruments
IntraSpec, Inc.	Oak Ridge	TN	SBIR		IT and instruments
LAMBDA INSTRUMENTS	Blacksburg	VA	SBIR		IT and instruments
LAMBDA INSTRUMENTS	Blacksburg	VA	SBIR		IT and instruments
Luna Innovations, Inc.	Blacksburg	VA	SBIR		IT and instruments
Luna Innovations, Inc.	Blacksburg	VA	SBIR		IT and instruments
Luna Innovations, Inc.	Blacksburg	VA	SBIR		IT and instruments
Luna Innovations, Inc.	Blacksburg	VA	SBIR		IT and instruments
PhotoSonic, Inc.	Blacksburg	VA	SBIR		IT and instruments
PRIME PHOTONICS, INC.	Blacksburg	VA	SBIR		IT and instruments
World Physics Tech., Inc.	Blacksburg	VA	SBIR	$100,000	IT and instruments
F&S, Inc.	Blacksburg	VA	SBIR		IT and instruments
F&S, Inc.	Blacksburg	VA	SBIR		IT and instruments
NanoSonic, Inc.	Christiansburg	VA	SBIR		IT and instruments
NanoSonic, Inc.	Christiansburg	VA	SBIR		IT and instruments
NanoSonic, Inc.	Christiansburg	VA	SBIR		IT and instruments
NanoSonic, Inc.	Christiansburg	VA	SBIR	$74,999	IT and instruments
Luna Innovations, Inc.	Blacksburg	VA	SBIR		IT and instruments
F&S, Inc.	Blacksburg	VA	SBIR		IT and instruments
Airak Engineering	New Castle	VA	SBIR	$100,000	IT and instruments
American Research Corporation of Virginia	Radford	VA	SBIR		IT and instruments
Touchstone Research Laboratory, Ltd	Triadelphia	WV	SBIR		IT and instruments
American Magnetics, Inc.	Oak Ridge	TN	STTR		IT and instruments
Envir Eng Group, Inc	Knoxville	TN	STTR	$448,547	IT and instruments
Luna Innovations, Inc.	Blacksburg	VA	STTR	$99,981	IT and instruments
Luna Innovations, Inc.	Blacksburg	VA	STTR	$99,962	IT and instruments
NanoSonic, Inc.	Christiansburg	VA	STTR		IT and instruments
Luna Innovations, Inc.	Blacksburg	VA	STTR		IT and instruments

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Appendix Table 11 *continued*

SBIR/STTR/ATP award winners in ARC region, FY 2000

Company Name	City	St.	Type	Amount	Technology
PPL Therapeutics, Inc.	Blacksburg	VA	ATP	$2,695,000	Pharm. and Medical Technologies
GEM PHARMACEUTICALS, INC.	PELHAM	AL	SBIR	$134,283	Pharm. and Medical Technologies
SOUTHERN BIOTECHNOLOGY	BIRMINGHAM	AL	SBIR	$106,000	Pharm. and Medical Technologies
VECTORLOGICS, INC.	BIRMINGHAM	AL	SBIR	$344,294	Pharm. and Medical Technologies
CFD Research Corp.	Huntsville	AL	SBIR	$500,766	Pharm. and Medical Technologies
X-RAY IMAGING INNOVATIONS	BIRMINGHAM	AL	SBIR	$113,923	Pharm. and Medical Technologies
BIOELASTICS RESEARCH, LTD	BIRMINGHAM	AL	SBIR	$373,079	Pharm. and Medical Technologies
IBBEX, INC.	BIRMINGHAM	AL	SBIR	$357,791	Pharm. and Medical Technologies
SOUTHERN BIOSYSTEMS, INC.	BIRMINGHAM	AL	SBIR	$99,579	Pharm. and Medical Technologies
VINE BROOK RESEARCH CORPORATION	BIRMINGHAM	AL	SBIR	$99,935	Pharm. and Medical Technologies
TRANSMOLECULAR, INC.	BIRMINGHAM	AL	SBIR	$260,053	Pharm. and Medical Technologies
ELGAVISH PARAMAGNETICS, INC.	BIRMINGHAM	AL	SBIR	$348,846	Pharm. and Medical Technologies
CYTRX CORPORATION	NORCROSS	GA	SBIR	$206,051	Pharm. and Medical Technologies
COMPUTER SOURCE	GAINESVILLE	GA	SBIR	$99,212	Pharm. and Medical Technologies
GLYCOBIOTICS, INC.	COMER	GA	SBIR	$100,000	Pharm. and Medical Technologies
BIOLINX, LLC	HAGERSTOWN	MD	SBIR	$114,270	Pharm. and Medical Technologies
Anasazi BioMedical Research, Inc.	WINSTON-SALEM	NC	SBIR	$105,000	Pharm. and Medical Technologies
Anasazi BioMedical Research, Inc.	Winston-Salem	NC	SBIR		Pharm. and Medical Technologies
CIELO INSTITUTE, INC	ASHEVILLE	NC	SBIR	$374,982	Pharm. and Medical Technologies
RED TAIL HAWK CORPORATION	BINGHAMTON	NY	SBIR	$98,797	Pharm. and Medical Technologies
BIOLIFE SOLUTIONS	BINGHAMTON	NY	SBIR	$189,747	Pharm. and Medical Technologies
BioLife Technologies Inc.	Binghamton	NY	SBIR	$100,000	Pharm. and Medical Technologies
TRANSONIC SYSTEMS, INC.	ITHACA	NY	SBIR	$531,710	Pharm. and Medical Technologies
BIOMED RESEARCH & TECHNOLOGIES	WEXFORD	PA	SBIR	$199,781	Pharm. and Medical Technologies
DYNAMIC CONTOURS, LLC	ALLISON PARK	PA	SBIR	$103,515	Pharm. and Medical Technologies
SEQUEL GENETICS, INC.	PITTSBURGH	PA	SBIR	$98,960	Pharm. and Medical Technologies
PROLX PHARMACEUTICALS, LP	PITTSBURGH	PA	SBIR	$1,087,690	Pharm. and Medical Technologies
BIOPORE, INC.	STATE COLLEGE	PA	SBIR	$98,925	Pharm. and Medical Technologies
REMCOM, INC.	State College	PA	SBIR		Pharm. and Medical Technologies
FOX FARSIGHT PRODUCTIONS, INC.	BRIDGEVILLE	PA	SBIR	$221,872	Pharm. and Medical Technologies
COMPUTATIONAL DIAGNOSTICS, INC.	PITTSBURGH	PA	SBIR	$237,525	Pharm. and Medical Technologies
CYBERGENETICS COMPANY	PITTSBURGH	PA	SBIR	$176,582	Pharm. and Medical Technologies
NEO GEN SCREENING, INC.	PITTSBURGH	PA	SBIR	$456,662	Pharm. and Medical Technologies
PSYCHOLOGY SOFTWARE TOOLS, INC.	PITTSBURGH	PA	SBIR	$382,079	Pharm. and Medical Technologies
AUTOMATED CELL, INC.	PITTSBURGH	PA	SBIR	$375,573	Pharm. and Medical Technologies
Clinical & Industrial Tech	Seneca	SC	SBIR	$399,892	Pharm. and Medical Technologies
ATOM SCIENCES, INC.	OAK RIDGE	TN	SBIR	$133,783	Pharm. and Medical Technologies
ATMOSPHERIC GLOW TECHNOLOGIES	KNOXVILLE	TN	SBIR	$102,430	Pharm. and Medical Technologies
SCI-TEC, INC.	KNOXVILLE	TN	SBIR	$124,251	Pharm. and Medical Technologies
BioNeutrics, Inc.	Knoxville	TN	SBIR		Pharm. and Medical Technologies
PETNet Pharmaceutical Services, Inc.	Knoxville	TN	SBIR		Pharm. and Medical Technologies
ApoCom, Inc.	Knoxville	TN	SBIR		Pharm. and Medical Technologies
TECHLAB, INC.	BLACKSBURG	VA	SBIR	$300,000	Pharm. and Medical Technologies
F&S, Inc./Luna Innovations, Inc.	Blacksburg	VA	SBIR	$69,953	Pharm. and Medical Technologies
American Research Corporation of Virginia	Radford	VA	SBIR	$200,000	Pharm. and Medical Technologies
SUMMIT CROSSROADS PRESS	BERKELEY	WV	SBIR	$98,166	Pharm. and Medical Technologies
Touchstone Research Laboratory, Ltd.	Triadelphia	WV	SBIR		Pharm. and Medical Technologies
CHEM-SPACE ASSOCIATES	PITTSBURGH	PA	SBIR	$99,844	Pharm. and Medical Technologies
F & S, Incorporated	Blacksburg	VA	STTR	$449,464	Pharm. and Medical Technologies
Automatika, Inc.	Pittsburgh	PA	SBIR		Other
Diamond Visionics Company	Vestal	NY	Tibbetts		Other
Transonic Systems, Inc.	Ithaca	NY	Tibbetts		Other
Cryomagnetics, Inc.	Oak Ridge	TN	Tibbetts		Other

Appendix Table 12

State-funded technology agencies and programs in ARC region

Name	City/Town	St.	Technology	Funding 2000	Type
Army Space and Missile Defense Command	Huntsville	AL	Aerospace		Research
NASA MSFC Tech Transfer Program	Huntsville	AL	Aerospace	$13,427,000	SBIR/STTR nationally
Army Aviation and Missile Command	Redstone Arsenal	AL	Aerospace	$95,000,000	Research
Center for Commercial Space Communications	Blacksburg	VA	Aerospace		Research
NSF Center for Materials Research,	Lexington	KY	Chemicals		Research
Center for Advanced Ceramic Technology	Alfred	NY	Chemicals		Research
Ceramics Corridor Innovation Center	Alfred	NY	Chemicals		Incubator
Material Research Science and Eng Center	Pittsburgh	PA	Chemicals	$900,000	Research
Center for Advanced Ceramic Materials	Blacksburg	VA	Chemicals		Research
Entrepreneurial Center,	Birmingham	AL	Comm. services, software	$600,000	Incubator
EBusiness Labs	Alpharetta	GA	Comm. services, software		Incubator
IT Alliance of Appalachian Ohio*	Athens	OH	Comm. services, software	N/A	Tech Cntr
Pittsburgh Digital Greenhouse	Pittsburgh	PA	Comm. services, software	$3,500,000	Research
Virtual Environments Lab	Morgantown	WV	Comm. services, software		Research
Byrd Center for Educational Technologies	Wheeling	WV	Comm. services, software		Research
Challenger Learning Center,	Wheeling	WV	Comm. services, software		Research
Center for Identification Technical Research (CITER) a NSF Center		WV	Comm. services, software		Research
Auburn Industrial Extension Service	Auburn	AL	Industrial Machinery	$900,000	MEP
Metropolitan Manufacturing Technology Center	Birmingham	AL	Industrial Machinery	$779,000	MEP
Bevill Manufacturing Technology Center	Gadsen	AL	Industrial Machinery	$1,083,000	MEP
Center for Automation and Robotics	Huntsville	AL	Industrial Machinery	$1,170,000	MEP
Alabama Productivity Center	Tuscaloosa	AL	Industrial Machinery	$569,000	MEP
Georgia Manufacturing Extension Partnership	Atlanta	GA	Industrial machinery		MEP
Georgia Tech, Econ Dev Institute Reg. Office	Carrolton	GA	Industrial machinery		MEP
Georgia Tech, Econ Dev Institute Reg. Office	Cartersville	GA	Industrial machinery		MEP
Georgia Tech, Econ Dev Institute Reg. Office	Dalton	GA	Industrial machinery		MEP
Georgia Tech, Econ Dev Institute Reg. Office	Gainsville	GA	Industrial machinery		MEP
Georgia Tech, Econ Dev Institute Reg. Office	Newman	GA	Industrial machinery		MEP
Georgia Tech, Econ Dev Institute Reg. Office	Rome	GA	Industrial machinery		MEP
Center for Manufacturing Systems	Lexington	KY	Industrial machinery		Research
Center for Robotics and Manufacturing Systems	Lexington	KY	Industrial machinery		Research
Kentucky Technology Service	Morehead	KY	Industrial machinery		MEP/SBIR
Kentucky Technology Service	Somerset	KY	Industrial machinery		MEP/SBIR
Technology Extension Service	Hagerstown	MD	Industrial machinery		MEP
NC Industrial Extension Service, MEP	Kings Mountain	NC	Industrial machinery		MEP
Alliance for Manufacturing and Technology	Binghamton	NY	Industrial machinery		MEP
Great Lakes Manufacturing Center***	Cleveland	OH	Industrial machinery	N/A	MEP
Manufacturing Resource Office***	Columbus	OH	Industrial machinery	N/A	MEP
NW PA Industrial Resource Center	Erie	PA	Industrial machinery		MEP
SW PA Industrial Resource Center	Pittsburgh	PA	Industrial machinery		MEP
Penn State Engineering Research Center	University Park	PA	Industrial machinery	$1,000,000	Research
Penn State Semiconductor Mfg Tech Initiative	University Park	PA	Industrial machinery	$2,000,000	Research
Manufacturing Technology Center	York	PA	Industrial machinery		MEP
Manufacturing Field Office	Greenville	SC	Industrial machinery		MEP
University of Tennessee Center for Industrial Services	Chattanooga	TN	Industrial machinery		MEP
The Manufacturing Center at Tennessee Technical Univ	Cookeville	TN	Industrial machinery		Research
University of Tennessee Center for Industrial Services	Knoxville	TN	Industrial machinery		MEP
Center for Coal and Mining Technologies	Blacksburg	VA	Industrial machinery		Research
NSF Center for Power Electronics	Blacksburg	VA	Industrial machinery		Research
VPMEP	Harrisonburg	VA	Industrial machinery		MEP
VPMEP	Roanoke	VA	Industrial machinery		MEP
Manufacturing Technology Center of SW VA	Wytheville	VA	Industrial machinery		MEP
WV MEP	Bridgeport	WV	Industrial machinery		MEP
Byrd Institute for Advanced Flexible Manufacturing	Huntington	WV	Industrial machinery		Research
WV MEP	Huntington	WV	Industrial machinery		MEP
WV MEP	Rocket Center	WV	Industrial machinery		MEP
WV MEP	South Charleston	WV	Industrial machinery		MEP
Lehigh Univ Center for Optical Technologies			Industrial machinery	$1,000,000	Research
Lehigh Univ Visteam Systems/PennState			Industrial machinery	$1,000,000	Research
BizTech	Huntsville	AL	IT and instruments	$225,000	Incubator
Integrated Electronics Engineering Center	Binghamton	NY	IT and instruments		Research
Fiber and Electro-optics Research Center	Blacksburg	VA	IT and instruments		Research
Center for Wireless Telecommunications	Blacksburg	VA	IT, instruments, Comm. services, software		Research

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Appendix Table 12 *continued*

State-funded technology agencies and programs in ARC region

Name	City/Town	St.	Technology	Funding 2000	Type
Ohio SBDC at Ohio University	Athens	OH	N/A	$222,823	SBIR
Ohio SBDC at OMEGA	Cambridge	OH	N/A	$16,755	SBIR
Ohio SBDC at Kent State U., Columbiana	East Liverpool	OH	N/A	$87,234	SBIR
Ohio SBDC at Southern State Community College	Hillsboro	OH	N/A	$74,930	SBIR
Ohio ITAC at Marietta College	Marietta	OH	N/A	$48,862	SBIR
SBDC at Marietta College	Marietta	OH	N/A	$159,653	SBIR
Ohio SBDC at Kent State U., Tuscarawas	New Philadelphia	OH	N/A	$101,129	SBIR
Ohio Mfg. SBDC at OSU Piketon	Piketon	OH	N/A	$26,688	SBIR
Southeast Ohio SBDC	Southpoint	OH	N/A	$160,344	SBIR
Ohio SBDC at Jefferson County	Steubenville	OH	N/A	$153,459	SBIR
Shoals Entrepreneurship Center	Florence	AL	Other	$330,000	Incubator
Center for Environmental Technology	Muscle Shoals	AL	Other	$779,000	MEP
Learning and Performance Support Lab,	Athens	GA	Other		Research
Center for Agriculture		MD	Other		Research
Georgia Biotechnology Center	Athens	GA	Pharm. and Medical Technologies		Research
Medical Imaging Development Center	Atlanta	GA	Pharm. and Medical Technologies		Research
Cornell Institute for Biotechnology & Life Sciences Technology	Ithaca	NY	Pharm. and Medical Technologies		Research
Edison Biotechnology Institute	Athens	OH	Pharm. and Medical Technc	$2,300,000	Res Cntr
Ohio University Innovation Center**	Athens	OH	Pharm. and Medical Technc	$111,000	Incubator
OADI Technology Center	Birmingham	AL	Pharm. and Medical Technc	$266,000	Incubator
Center for Textile and Apparel Technology	Alexander City	AL	Textile and Apparel	$595,000	MEP
Alabama EPSCOR	statewide	AL		$14,200,000	Research
Alabama Research Institute	statewide	AL		$400,000	Research
Technology Assistance Program	statewide	AL		in-kind only	SBIR
Carroll Business Incubator	Carrolton	GA			Incubator
SBIR Resource Program at Kennesaw State Univ.	Kennesaw	GA			SBIR
EPSCOR program		KY			Research
Hagerstown Community College Technology Innovation Ctr	Hagerstown	MD			Incubators
Allegany-Garrett ATC		MD			Research
Challenge Investment Program (Western winners?)		MD			Research
Maryland Industrial Partnership Program (Western winners?)		MD			Research
Potomac ATC		MD			Research
Regional Managers of DBED		MD			SBIR
Strategic Investment Fund (Western winners?)		MD			Research
Western MD SBDC		MD			SBIR
Northeast Business Incubator System	Corinth	MS			Incubator
North Mississippi Entrepreneurship Institute	Oxford	MS			Incubator
Mississippi Research Consortium (EPSCOR)	Starkville	MS			Research
Mississippi Technology Center	Starkville	MS			Incubator
NC SBTDC	Asheville	NC			SBIR
NC SBTDC	Boone	NC			SBIR
Haywood Community College	Clyde	NC			MEP
NC SBTDC	Cullowhee	NC			SBIR
Catawba Valley Community College	Hickory	NC			MEP
NC SBTDC	Hickory	NC			SBIR
NC SBTDC	Winston-Salem	NC			SBIR
MVATC Technology and Incubator Center	Utica	NY			Incubator
Ben Franklin Partnership – North East	Bethlehem	PA			Incubator/SBIR
Innovation Works, Inc.	Pittsburgh	PA			Incubator/SBIR
Ben Franklin Partnership– Central and Northern	University Park	PA			Incubator/SBIR
PENNTAP, Penn State Technical Assistance Program	University Park	PA		$655,014	MEP
Clemson Research Park	Clemson	SC			Research
SBDC-Clemson University Region	Clemson	SC			SBIR
First Base Ventures	Greenville	SC			Incubator
SBDC-Greenville Area	Greenville	SC			SBIR
SBDC-Spartanburg Area	Greenville	SC			SBIR
SBDC-Upper Savannah Area	Greenwood	SC			SBIR
EPSCOR		SC			Research
Chattanooga/Hamilton Business Development Center	Chattanooga	TN			SBIR
SE Development District	Chattanooga	TN			SBIR
Cleveland State Community College	Cleveland	TN			SBIR
Regional Business Technology Incubator	Cookeville	TN			Incubator
East Tennessee State University	Johnson City	TN			SBIR

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Appendix Table 12 *continued*

State-funded technology agencies and programs in ARC region

Name	City/Town	St.	Technology	Funding 2000	Type
Fairview Technology Center	Knoxville	TN			Incubator
Pellisippi State Technical Community College	Knoxville	TN			SBIR
Tennessee Technology Development Corporation	Knoxville	TN			Research
Oak Ridge Incubation Center	Oak Ridge	TN			Incubator
Technology 2020	Oak Ridge	TN			Incubator
Tennessee Research Institute		TN			
TSBDCs		TN			
Business-Technology Center	Blacksburg	VA			Incubator
CIT	Blacksburg	VA			SBIR
CIT	Roanoke	VA			SBIR
CIT	Wise	VA			SBIR
PROMISE		WV			SBIR
W.Va. EPSCOR		WV			Research

Appendix Table 13

Science and engineering CIP codes

Science and engineering *Classification of Instructional Programs* codes by major disciplinary areas

Aggregated disciplinary area	CIP code title	CIP code
Aerospace Engineering, Aviation Science	Aerospace, Aeronautical & Astronautic	14.0201
& Astrophysics	Aeronautical & Aerospace Engineering Tech	15.0801
	Aviation & Airway Science	49.0101
	Astrophysics	40.0301
Biochemistry & Biomedical Engineering	Biochemistry	26.0202
	Biophysics	26.0203
	Bioengineering & Biomedical Engineering	14.0501
	Biological & Physical Sciences	30.0101
	Biopsychology	30.1001
Botany, Biology, Bacteriology	Botany, General	26.0301
& Biotechnology	Plant Pathology	26.0305
	Plant Physiology	26.0307
	Botany, Other	26.0399
	Cell Biology	26.0401
	Molecular Biology	26.0402
	Cell & Molecular Biology, Other	26.0499
	Biology, General	26.0101
	Biological Sciences/life Sciences, Other	26.9999
	Biological Tech./technician	41.0101
	Microbiology/bacteriology	26.0501
	Anatomy	26.0601
	Ecology	26.0603
	Marine/aquatic Biology	26.0607
	Neuroscience	26.0608
	Nutritional Sciences	26.0609
	Parasitology	26.0610
	Radiation Biology/radiobiology	26.0611
	Toxicology	26.0612
	Genetics, Plant & Animal	26.0613
	Biometrics	26.0614
	Biostatistics	26.0615
	Biotechnology Research	26.0616
	Evolutionary Biology	26.0617
	Biological Immunology	26.0618
	Virology	26.0619
	Misc. Biological Specializations, Oth.	26.0699
Communications & Computer Sciences	Educational/instructional Media Tech.	10.0101
& Technologies	Photographic Tech./technician	10.0103
	Radio & Television Broadcasting Tech.	10.0104
	Communications Technol./technicians, Oth	10.0199
	Computer & Information Sciences, Gen.	11.0101
	Computer Programming	11.0201
	Data Processing Tech./technician	11.0301
	Information Sciences & Systems	11.0401
	Computer Systems Analysis	11.0501
	Computer Science	11.0701
	Computer & Information Sciences, Other	11.9999
	Computer Engineering	14.0901
	Computer Engineering Tech./technician	15.0301
	Electrical, Electronics & Communication	14.1001
	Elec., Electronic & Comm. Engin. Tech.	15.0303
	Laser & Optical Tech./technician	15.0304
	Electrical & Electronic Engin.-rel. Tech	15.0399

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Appendix Table 13 *continued*

Science and engineering CIP codes

Science and engineering *Classification of Instructional Programs* codes by major disciplinary areas

Aggregated disciplinary area	CIP code title	CIP code
Environmental Engineering & Controls	Water Quality/wastewater Treatment Tech	15.0506
	Environmental & Pollution Control Tech.	15.0507
	Environmental Control Tech, Oth.	15.0599
	Environmental/environmental Health Engin	14.1401
Agricultural Sciences & Technology	Agricultural Engineering	14.0301
	Agriculture/agricultural Sciences, Gen.	02.0101
	Agriculture/agricultural Sciences, Other	02.9999
	Animal Sciences, General	02.0201
	Agricultural Animal Breeding & Genetics	02.0202
	Agricultural Animal Health	02.0203
	Agricultural Animal Nutrition	02.0204
	Agricultural Animal Physiology	02.0205
	Dairy Science	02.0206
	Poultry Science	02.0209
	Animal Sciences, Other	02.0299
	Food Sciences & Tech.	02.0301
	Plant Sciences, General	02.0401
	Agronomy & Crop Science	02.0402
	Horticulture Science	02.0403
	Plant Breeding & Genetics	02.0405
	Agricultural Plant Pathology	02.0406
	Agricultural Plant Physiology	02.0407
	Plant Protection (pest Management)	02.0408
	Range Science & Management	02.0409
	Plant Sciences, Other	02.0499
	Soil Sciences	02.0501
	Zoology, General	26.0701
	Entomology	26.0702
	Pathology, Human & Animal	26.0704
	Pharmacology, Human & Animal	26.0705
	Physiology, Human & Animal	26.0706
	Zoology, Other	26.0799
Forestry Science & Forestry Technology	Forest Harvesting & Production Tech.	03.0401
	Forest Products Tech./technician	03.0404
	Forestry Sciences	03.0502
	Wood Science & Pulp/paper Tech.	03.0509
	Forestry & Related Sciences, Other	03.0599
Geological & Geophysical Engineering	Atmospheric Sciences & Meteorology	40.0401
	Geology	40.0601
	Geochemistry	40.0602
	Geophysics & Seismology	40.0603
	Geological & Related Sciences, Other	40.0699
	Earth & Planetary Sciences	40.0703
	Geological Engineering	14.1501
	Geophysical Engineering	14.1601
	Mining Tech./technician	15.0901
	Petroleum Tech./technician	15.0903
	Mining & Petroleum Technol./tech, Other	15.0999
	Mining & Mineral Engineering	14.2101
	Ocean Engineering	14.2401
	Petroleum Engineering	14.2501

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Appendix Table 13 *continued*

Science and engineering CIP codes

Science and engineering *Classification of Instructional Programs* codes by major disciplinary areas

Aggregated disciplinary area	CIP code title	CIP code
Mathematics	Operations Research	27.0302
	Applied Mathematics, Other	27.0399
	Mathematical Statistics	27.0501
	Mathematics, Other	27.9999
	Mathematics	27.0101
	Applied Mathematics, General	27.0301
	Mathematics & Computer Science	30.0801
Basic Medical Science	Medical Anatomy	51.1301
	Medical Biochemistry	51.1302
	Medical Physics/biophysics	51.1304
	Medical Cell Biology	51.1305
	Medical Genetics	51.1306
	Medical Immunology	51.1307
	Medical Microbiology	51.1308
	Medical Molecular Biology	51.1309
	Medical Neurobiology	51.1310
	Medical Nutrition	51.1311
	Medical Pathology	51.1312
	Medical Physiology	51.1313
	Medical Toxicology	51.1314
	Basic Medical Sciences, Other	51.1399
Physics & Nuclear Engineering	Nuclear Engineering	14.2301
	Physical Sciences, General	40.0101
	Miscellaneous Physical Sciences, Other	40.0799
	Physical Sciences, Other	40.9999
	Physical Science Technol./technicians, Oth	41.0399
	Science Technol./technicians, Other	41.9999
	Physics, General	40.0801
	Chemical & Atomic/molecular Physics	40.0802
	Elementary Particle Physics	40.0804
	Plasma & High-temperature Physics	40.0805
	Nuclear Physics	40.0806
	Optics	40.0807
	Solid State & Low-temperature Physics	40.0808
	Acoustics	40.0809
	Theoretical & Mathematical Physics	40.0810
	Physics, Other	40.0899
Industrial Engineering & Technology	Industrial/manufacturing Tech/technician	15.0603
	Plastics Tech./technician	15.0607
	Metallurgical Tech./technician	15.0611
	Industrial Product. Technol./techn, Oth	15.0699
	Quality Control Tech./technician	15.0702
	Hydraulic Tech./technician	15.1103
	Industrial/manufacturing Engineering	14.1701
	Industrial Radiologic Tech./technician	41.0204
	Nuclear/nuclear Power Tech./technician	41.0205
	Nuclear & Industrial Radiologic Tech.,other	41.0299
	Textile Sciences & Engineering	14.2801

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Appendix Table 13 *continued*

Science and engineering CIP codes

Science and engineering *Classification of Instructional Programs* codes by major disciplinary areas

Aggregated disciplinary area	CIP code title	CIP code
Mechanical Engineering, Engineering Physics & Science, & Systems Engineering	Biomedical Engineering-related Tech.	15.0401
	Computer Main. Tech./technician	15.0402
	Electromechanical Tech./technician	15.0403
	Instrumentation Tech./technician	15.0404
	Robotics Tech./technician	15.0405
	Electromechanical Instrum. & Maint. Tech	15.0499
	Heating, Air Condition. & Refrig. Tech.	15.0501
	Energy Management & Systems Tech./techn	15.0503
	Engineering Design	14.2901
	Engineering Mechanics	14.1101
	Engineering Physics	14.1201
	Engineering Science	14.1301
	Engineering, General	14.0101
	Engineering-related Tech/technician, Gen	15.1101
	Engineering, Other	14.9999
	Engineering-related Technol./techn, Oth	15.9999
	Mechanical Engineering	14.1901
	Automotive Engineering Tech./technician	15.0803
	Mechanical Engineering/mechanical Tech.	15.0805
	Mechanical Engineering-related Tech, Oth	15.0899
	Systems Engineering	14.2701
	Systems Science & Theory	30.0601
Materials Engineering & Science	Ceramic Sciences & Engineering	14.0601
	Material Engineering	14.1801
	Materials Science	14.3101
	Metallurgical Engineering	14.2001
	Metallurgy	40.0701
	Polymer/plastics Engineering	14.3201
Chemical Engineering & Technology	Chemical Engineering	14.0701
	Organic Chemistry	40.0504
	Chemistry, General	40.0501
	Analytical Chemistry	40.0502
	Inorganic Chemistry	40.0503
	Medicinal/pharmaceutical Chemistry	40.0505
	Physical & Theoretical Chemistry	40.0506
	Polymer Chemistry	40.0507
	Chemistry, Other	40.0599
	Chemical Tech./technician	41.0301

Appendix Table 14

Selected excluded CIP codes

CIPs considered, but not included, in final list of science & engineering programs

CIP code title	CIP code	CIP code title	CIP code
Agricultural Business And Mgmt., General	01.0101	Financial Services Marketing Operations	08.0401
Agricultural Business/agribusiness Oper	01.0102	Floristry Marketing Operations	08.0503
Agricultural Economics	01.0103	Food Products Retail And Wholesale Opns	08.0601
Farm And Ranch Management	01.0104	Auctioneering	08.0701
Agricultural Business & Management, Oth	01.0199	General Buying Operations	08.0704
Agricultural Mechanization, General	01.0201	General Retailing Operations	08.0705
Agricultural Power Machinery Operator	01.0204	General Selling Skills And Sales Opns.	08.0706
Agricultural Mechanization, Other	01.0299	General Marketing Operations	08.0708
Ag. Prod. Workers And Managers, Gen.	01.0301	General Distribution Operations	08.0709
Ag. Animal Husbandry & Prod. Mgmt.	01.0302	Gen. Retail & Whlsale Opns. & Skills,oth	08.0799
Aquaculture Operations And Prod. Mgmt.	01.0303	Home Products Marketing Operations	08.0809
Crop Production Operations & Management	01.0304	Home & Office Products Mrkting Opns, Oth	08.0899
Ag. Prod. Workers And Managers, Other	01.0399	Hospitality & Rec. Marketing Opns, Gen	08.0901
Ag. & Food Products Process. Op. & Mgmt	01.0401	Hotel/motel Serv. Marketing Operation	08.0902
Ag. Supplies Retailing & Wholesaling	01.0501	Recreation Products/serv. Marketing Opns	08.0903
Animal Trainer	01.0505	Food Sales Operations	08.0906
Eques./equine Stds., Horse Mgmt. & Trgn	01.0507	Hospitality & Recrtn. Market. Opns, Oth	08.0999
Ag. Supplies And Related Svcs, Other	01.0599	Insurance Marketing Operations	08.1001
Horticulture Svcs. Ops. And Mgmt., Gen.	01.0601	Tourism Promotion Operations	08.1104
Ornamental Horticulture Ops. And Mgmt.	01.0603	Travel Services Marketing Operations	08.1105
Greenhouse Operations And Management	01.0604	Tourism & Travel Serv. Market. Opns,oth	08.1199
Landscaping Operations And Management	01.0605	Vehicle Parts & Accessories Market. Opn	08.1203
Nursery Operations And Management	01.0606	Vehicle Marketing Operations	08.1208
Turf Management	01.0607	Vehicle & Petrol. Prods. Market. Ops, Oth	08.1299
Horticulture Svcs. Ops. And Mgmt., Oth.	01.0699	Health Products & Services Marketing Ops	08.1301
International Agriculture	01.0701	Marketing Opns/market. & Distrib.,other	08.9999
Agricultural Business & Production, Oth	01.9999	Communications, General	09.0101
Agricultural Extension	02.0102	Advertising	09.0201
Natural Resources Conservation, General	03.0101	Journalism	09.0401
Environmental Science/studies	03.0102	Broadcast Journalism	09.0402
Natural Resources Management And Policy	03.0201	Mass Communications	09.0403
Nat. Resrcs. Law Enforce. & Protect. Svc	03.0203	Journalism And Mass Communication, Other	09.0499
Nat. Resrcs. Mgmt. & Protectv Svcs, Oth	03.0299	Public Relations & Organizational Comm.	09.0501
Fishing And Fisheries Sciences And Mgmt	03.0301	Radio And Television Broadcasting	09.0701
Forest Production And Processing, Other	03.0499	Communications, Other	09.9999
Forestry, General	03.0501	Card Dealer	12.0203
Forest Management	03.0506	Gaming & Sports Officiating Serv., Oth.	12.0299
Wildlife And Wildlands Management	03.0601	Funeral Services And Mortuary Science	12.0301
Conservation & Renewable Nat. Resrs, Other	03.9999	Cosmetic Services, General	12.0401
Apparel & Accessories Market. Opns, Gen	08.0101	Barber/hairstylist	12.0402
Fashion Merchandising	08.0102	Cosmetologist	12.0403
Fashion Modeling	08.0103	Electrolysis Technician	12.0404
Apparel & Accessories Market. Opns, Other	08.0199	Massage	12.0405
Business Services Marketing Operations	08.0204	Make-up Artist	12.0406
Personal Svcs Marketing Operations	08.0205	Cosmetic Services, Other	12.0499
Bus. & Personal Ser. Market. Opns, Oth	08.0299	Baker/pastry Chef	12.0501
Entrepreneurship	08.0301	Bartender/mixologist	12.0502
Culinary Arts/chef Training	12.0503	Aircraft Mechanic/technician, Airframe	47.0607
Food & Beverage/restaurant Opns. Manager	12.0504	Aircraft Mechanic/technician, Powerplant	47.0608
Kitchen Personnel/cook & Asst. Trng.	12.0505	Aviation Systems And Avionics Main. Tech	47.0609
Meatcutter	12.0506	Motorcycle Mechanic And Repairer	47.0611
Waiter/waitress And Dining Room Manager	12.0507	Vehicle & Mobile Equip. Mechanics & Repair	47.0699

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Appendix Table 14 *continued*

Selected excluded CIP codes

CIPs considered, but not included, in final list of science & engineering programs

CIP code title	CIP code	CIP code title	CIP code
Culinary Arts & Related Services, Other	12.0599	Mechanics And Repairers, Other	47.9999
Personal & Miscellaneous Services, Other	12.9999	Drafting, General	48.0101
Architectural Engineering	14.0401	Architectural Drafting	48.0102
Civil Engineering, General	14.0801	Civil/structural Drafting	48.0103
Geotechnical Engineering	14.0802	Electrical/electronics Drafting	48.0104
Structural Engineering	14.0803	Mechanical Drafting	48.0105
Transportation And Highway Engineering	14.0804	Drafting, Other	48.0199
Water Resources Engineering	14.0805	Graphic & Printing Equip. Operator, Gen	48.0201
Civil Engineering, Other	14.0899	Mechanical Typesetter And Composer	48.0205
Naval Architecture & Marine Engineering	14.2201	Lithographer And Platemaker	48.0206
Engineering/industrial Management	14.3001	Printing Press Operator	48.0208
Architectural Engineering Techno/tech	15.0101	Computer Typography & Composition Equip	48.0211
Civil Engineering/civil Tech./technician	15.0201	Desktop Publishing Equipment Operator	48.0212
Occupational Safety & Health Tech./techn	15.0701	Graphic & Printing Equip. Operator, Oth	48.0299
Quality Control & Safety Technol./tech.	15.0799	Upholsterer	48.0303
Construction/building Tech./technician	15.1001	Shoe, Boot And Leather Repairer	48.0304
Surveying	15.1102	Leatherworkers And Upholsterers, Other	48.0399
Astronomy	40.0201	Machinist/machine Technologist	48.0501
Paleontology	40.0604	Machine Shop Assistant	48.0503
Oceanography	40.0702	Sheet Metal Worker	48.0506
Electrical And Electronics Equipment Ins	47.0101	Tool And Die Maker/technologist	48.0507
Business Machine Repairer	47.0102	Welder/welding Technologist	48.0508
Communication Sys. Installer & Repairer	47.0103	Precision Metal Workers, Other	48.0599
Computer Installer And Repairer	47.0104	Woodworkers, General	48.0701
Indus. Electronics Installer & Repairer	47.0105	Furniture Designer And Maker	48.0702
Major Appliance Installer And Repairer	47.0106	Cabinet Maker And Millworker	48.0703
Electrical And Electronics Equipment Ins	47.0199	Woodworkers, Other	48.0799
Heating, Air Conditioning And Refrigerat	47.0201	Precision Production Trades, Other	48.9999
Heavy Equipment Main. And Repairer	47.0302	Aircraft Pilot And Navigator (professional)	49.0102
Industrial Machinery Main. And Repairer	47.0303	Aviation Management	49.0104
Indus. Equip. Main. And Repairers, Oth.	47.0399	Air Traffic Controller	49.0105
Instrument Calibration And Repairer	47.0401	Flight Attendant	49.0106
Gunsmith	47.0402	Aircraft Pilot (private)	49.0107
Locksmith And Safe Repairer	47.0403	Air Transportation Workers, Other	49.0199
Musical Instrument Repairer	47.0404	Construction Equipment Operator	49.0202
Watch, Clock And Jewelry Repairer	47.0408	Truck, Bus & Oth. Commercial Vehicle Op	49.0205
Miscellaneous Mechanics & Repairers, Oth	47.0499	Vehicle And Equipment Operators, Other	49.0299
Stationary Energy Sources Installer/oper	47.0501	Fishing Tech/comm Fishing	49.0303
Auto/automotive Body Repairer	47.0603	Diver (professional)	49.0304
Auto/automotive Mechanic/technician	47.0604	Marine Main. And Ship Repairer	49.0306
Diesel Engine Mechanic And Repairer	47.0605	Marine Science/merchant Marine Officer	49.0309
Small Engine Mechanic And Repairer	47.0606	Water Transportation Workers, Other	49.0399
Transportation And Materials Moving Work	49.9999	Medical Laboratory Technician	51.1004
Chiropractic (d.c., D.c.m.)	51.0101	Medical Technology	51.1005
Communication Disorders, General	51.0201	Optometric/ophthalmic Laboratory Tech.	51.1006
Audiology/hearing Sciences	51.0202	Health & Medical Laboratory Tech., Oth.	51.1099
Speech-language Pathology	51.0203	Pre-dentistry Studies	51.1101
Speech-language Pathology And Audiology	51.0204	Pre-medicine Studies	51.1102
Sign Language Interpreter	51.0205	Pre-pharmacy Studies	51.1103
Communication Disorders Sci & Serv, Oth	51.0299	Pre-veterinary Studies	51.1104
Community Health Liaison	51.0301	Health & Med. Preparatory Programs, Oth	51.1199
Dentistry (d.d.s., D.m.d.)	51.0401	Medicine (m.d.)	51.1201

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Appendix Table 14 *continued*

Selected excluded CIP codes

CIPs considered, but not included, in final list of science & engineering programs

CIP code title	CIP code	CIP code title	CIP code
Dental Clinical Sciences/graduate Dentis	51.0501	Medical Clinical Sciences (m.s., Ph.d.)	51.1401
Dental Assistant	51.0601	Alcohol/drug Abuse Counseling	51.1501
Dental Hygienist	51.0602	Psychiatric/mental Health Services Tech	51.1502
Dental Laboratory Technician	51.0603	Clinical And Medical Social Work	51.1503
Dental Services, Other	51.0699	Mental Health Services, Other	51.1599
Health System/health Services Admin.	51.0701	Nursing (r.n. Training)	51.1601
Hospital/health Facilities Admin.	51.0702	Nursing Administration (post-r.n.)	51.1602
Health Unit Coordinator/ward Clerk	51.0703	Nursing, Adult Health (post-r.n.)	51.1603
Health Unit Manager/ward Supervisor	51.0704	Nursing Anesthetist (post-r.n.)	51.1604
Medical Office Management	51.0705	Nursing, Family Practice (post-r.n.)	51.1605
Medical Records Administration	51.0706	Nursing, Maternal/child Health (post-r.	51.1606
Medical Records Tech./technician	51.0707	Nursing Midwifery (post-r.n.)	51.1607
Medical Transcription	51.0708	Nursing Science (post-r.n.)	51.1608
Health & Medical Admin. Services, Oth.	51.0799	Nursing, Pediatric (post-r.n.)	51.1609
Medical Assistant	51.0801	Nursing, Psych./mental Health (post-r.n	51.1610
Medical Laboratory Assistant	51.0802	Nursing, Public Health (post-r.n.)	51.1611
Occupational Therapy Assistant	51.0803	Nursing, Surgical (post-r.n.)	51.1612
Ophthalmic Medical Assistant	51.0804	Practical Nurse (l.p.n. Training)	51.1613
Pharmacy Technician/assistant	51.0805	Nurse Assistant/aide	51.1614
Physical Therapy Assistant	51.0806	Home Health Aide	51.1615
Physician Assistant	51.0807	Nursing, Other	51.1699
Veterinarian Assistant/animal Health Tec	51.0808	Optometry (o.d.)	51.1701
Health And Medical Assistants, Other	51.0899	Opticianry/dispensing Optician	51.1801
Cardiovascular Tech./technician	51.0901	Optical Technician/assistant	51.1802
Electrocardiograph Tech./technician	51.0902	Ophthalmic Medical Technologist	51.1803
Electroencephalograph Tech./technician	51.0903	Orthoptics	51.1804
Emergency Medical Tech./technician	51.0904	Ophthalmic/optometric Services, Other	51.1899
Nuclear Medical Tech./technician	51.0905	Osteopathic Medicine (d.o.)	51.1901
Perfusion Tech./technician	51.0906	Pharmacy (b. Pharm., Pharm.d.)	51.2001
Medical Radiologic Tech./technician	51.0907	Pharmacy Administration & Pharmaceutics	51.2002
Respiratory Therapy Technician	51.0908	Medical Pharmacology & Pharmaceutical Sci	51.2003
Surgical/operating Room Technician	51.0909	Pharmacy, Other	51.2099
Diagnostic Medical Sonography	51.0910	Podiatry (d.p.m., D.p., Pod.d.)	51.2101
Health & Med. Diagnostic & Treat Svc, Ot	51.0999	Public Health, General	51.2201
Blood Bank Tech./technician	51.1001	Environmental Health	51.2202
Cytotechnologist	51.1002	Epidemiology	51.2203
Hematology Tech./technician	51.1003	Health And Medical Biostatistics	51.2204
Health Physics/radiologic Health	51.2205	Franchise Operation	52.0702
Occupational Health & Industrial Hygiene	51.2206	Enterprise Management & Operation, Oth.	52.0799
Public Health Education And Promotion	51.2207	Finance, General	52.0801
Public Health, Other	51.2299	Actuarial Science	52.0802
Art Therapy	51.2301	Banking And Financial Support Services	52.0803
Dance Therapy	51.2302	Financial Planning	52.0804
Hypnotherapy	51.2303	Insurance And Risk Management	52.0805
Movement Therapy	51.2304	International Finance	52.0806
Music Therapy	51.2305	Investments And Securities	52.0807
Occupational Therapy	51.2306	Public Finance	52.0808
Orthotics/prosthetics	51.2307	Financial Management And Services, Other	52.0899
Physical Therapy	51.2308	Hospitality/administration Management	52.0901
Recreational Therapy	51.2309	Hotel/motel And Restaurant Management	52.0902
Vocational Rehabilitation Counseling	51.2310	Travel-tourism Management	52.0903
Rehabilitation/therapeutic Services, Oth	51.2399	Hospitality Services Management, Other	52.0999

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Appendix Table 14 *continued*

Selected excluded CIP codes

CIPs considered, but not included, in final list of science & engineering programs

CIP code title	CIP code	CIP code title	CIP code
Veterinary Medicine (d.v.m.)	51.2401	Human Resources Management	52.1001
Veterinary Clinical Sciences (m.s., Ph.d.)	51.2501	Labor/personnel Relations And Studies	52.1002
Health Aide	51.2601	Organizational Behavior Studies	52.1003
Acupuncture And Oriental Medicine	51.2701	Human Resources Management, Other	52.1099
Medical Dietician	51.2702	International Business	52.1101
Medical Illustrating	51.2703	Mgmt. Info. Systems & Bus. Data Process	52.1201
Naturopathic Medicine	51.2704	Business Computer Programming/programmer	52.1202
Psychoanalysis	51.2705	Business Systems Analysis And Design	52.1203
Health Professions & Rel. Sciences, Oth	51.9999	Business Systems Networking And Telecomm	52.1204
Business, General	52.0101	Business Computer Facilities Operator	52.1205
Business Administration & Mgmt., Gen.	52.0201	Business Information And Data Processing	52.1299
Purchasing, Procurement & Contracts Mgmt	52.0202	Management Science	52.1301
Logistics And Materials Management	52.0203	Business Statistics	52.1302
Office Supervision And Management	52.0204	Bus. Quantitative Methods & Mgmt.,oth.	52.1399
Operations Management And Supervision	52.0205	Business Marketing/marketing Management	52.1401
Non-profit And Public Management	52.0206	Marketing Research	52.1402
Business Administration & Mgmt., Oth.	52.0299	International Business Marketing	52.1403
Accounting	52.0301	Marketing Management And Research, Other	52.1499
Accounting Technician	52.0302	Real Estate	52.1501
Accounting, Other	52.0399	Taxation	52.1601
Administrative Assistant/secretarial Sci	52.0401	Business Management & Admin. Serv., Oth	52.9999
Executive Assistant/secretary	52.0402		
Legal Administrative Assistant/secretary	52.0403		
Medical Administrative Asst./secretary	52.0404		
Court Reporter	52.0405		
Receptionist	52.0406		
Information Processing/data Entry Tech.	52.0407		
General Office/clerical & Typing Serv.	52.0408		
Administrative & Secretarial Serv., Oth	52.0499		
Business Communications	52.0501		
Business/managerial Economics	52.0601		
Enterprise Management & Operation, Gen.	52.0701		

Note: Specific codes were selected from the following major CIP categories: 01 (Agricultural business and production), 02 (Agricultural sciences), 03 (Conservation and renewable natural resources), 08 (Marketing operations, marketing and distribution), 09 (Communications), 10 (Communications technologies), 11 (Computer and information sciences), 12 (Personal and miscellaneous services), 14 (Engineering), 15 (Engineering-related technologies), 26 (Biological sciences/life sciences), 27 (Mathematics), 40 (Physical sciences), 41 (Science technologies), 47 (Mechanics and repairers), 48 (Precision production trades), 49 (transportation and materials moving workers), 51 (Health professions and related sciences), and 52 (business management and administrative services). See text discussion of criteria of selection within each category.