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.

---

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

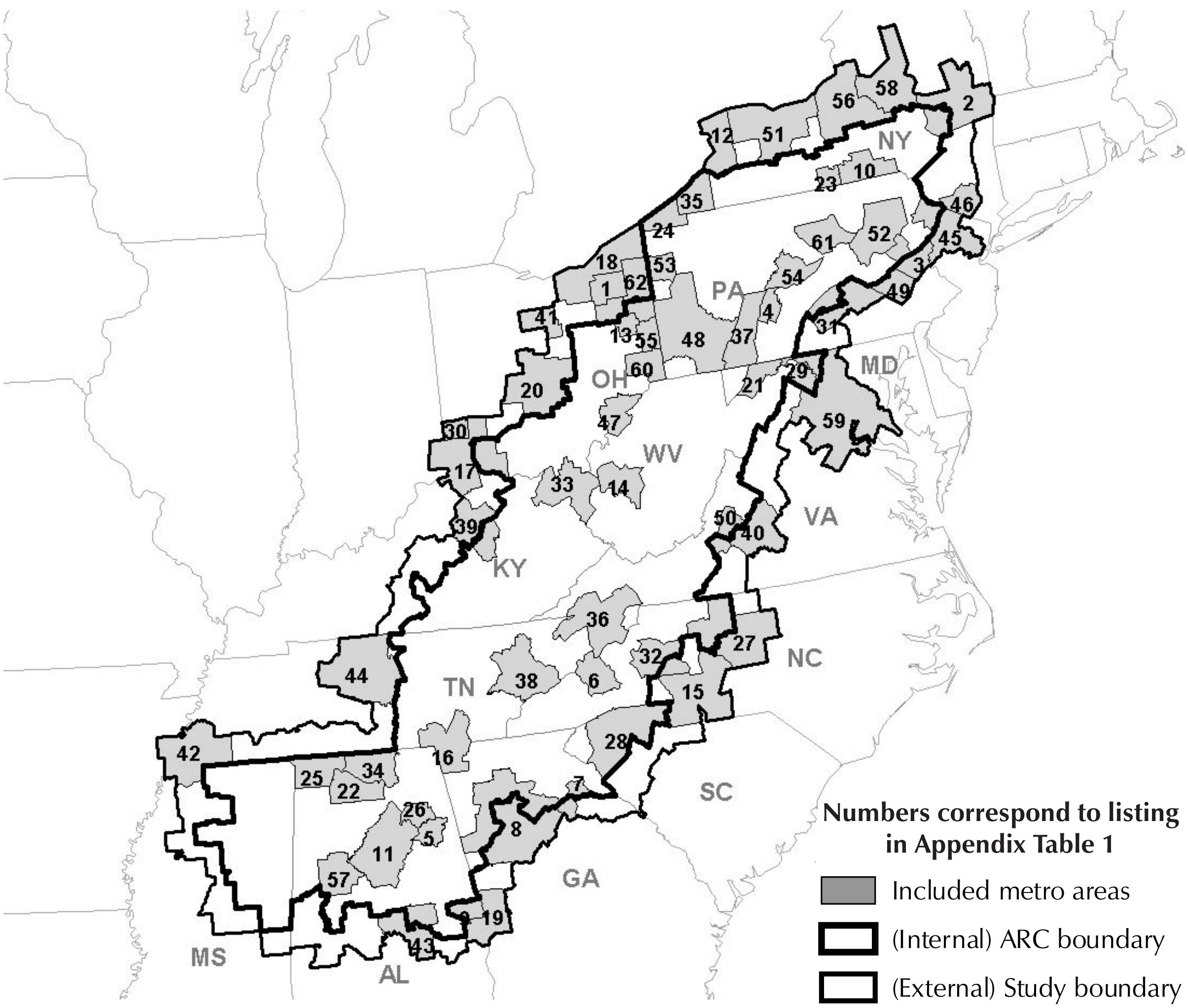
11. The ES-202 file reports employment and wage data for all firms subject to federal and state employment security law, with only the very smallest enterprises and sole proprietorships excluded. At the time of study, 1998 was the most recent year available, with reliable data stretching back to 1989. 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.

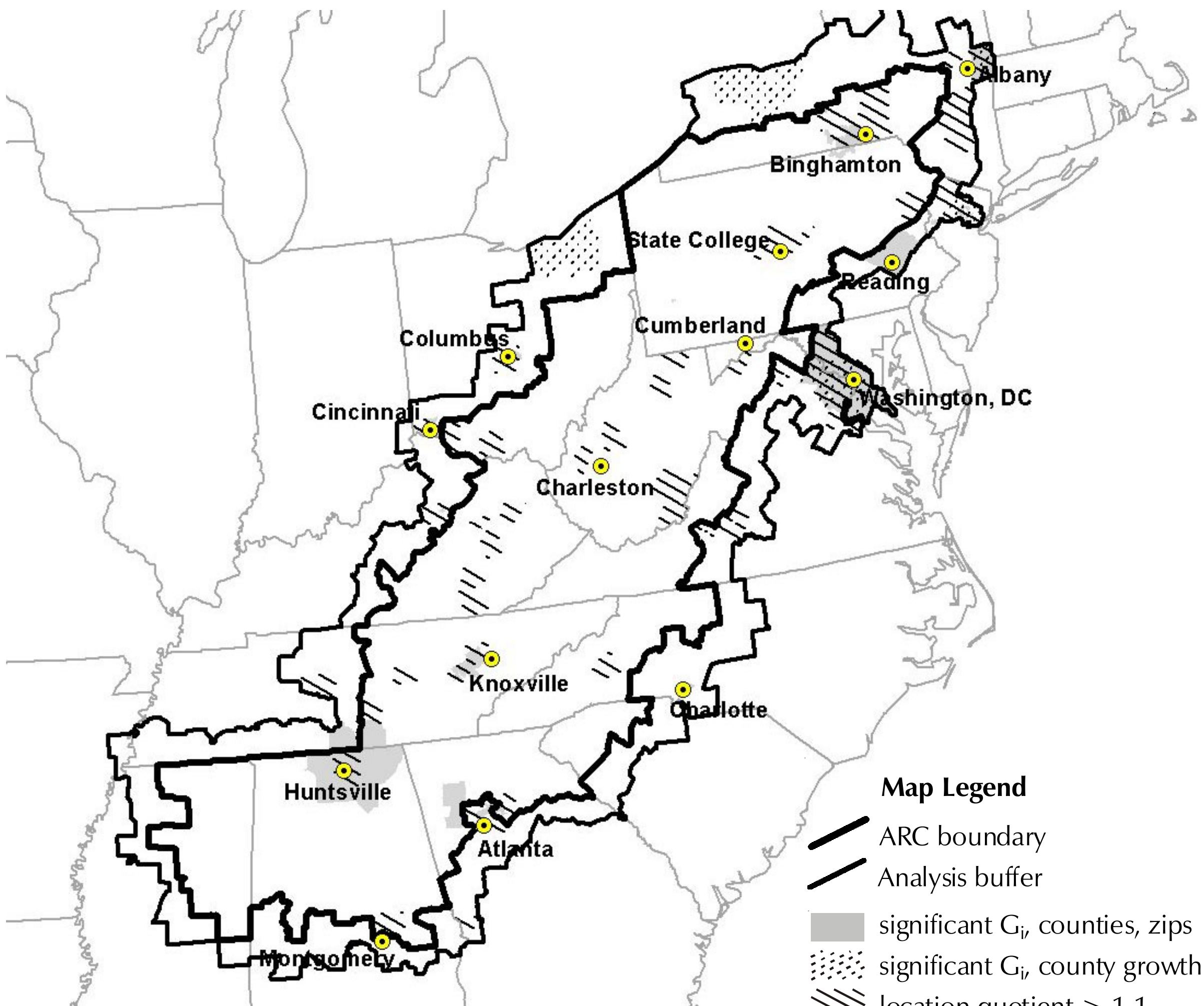
While MTI concentrations are distributed throughout Appalachia, concentrations of STI employment and employment growth are oriented toward the north (in New York, Pennsylvania, and Ohio) and the south (Tennessee, the Carolinas, Georgia and Alabama). Interestingly, there are no substantial STI concentrations 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

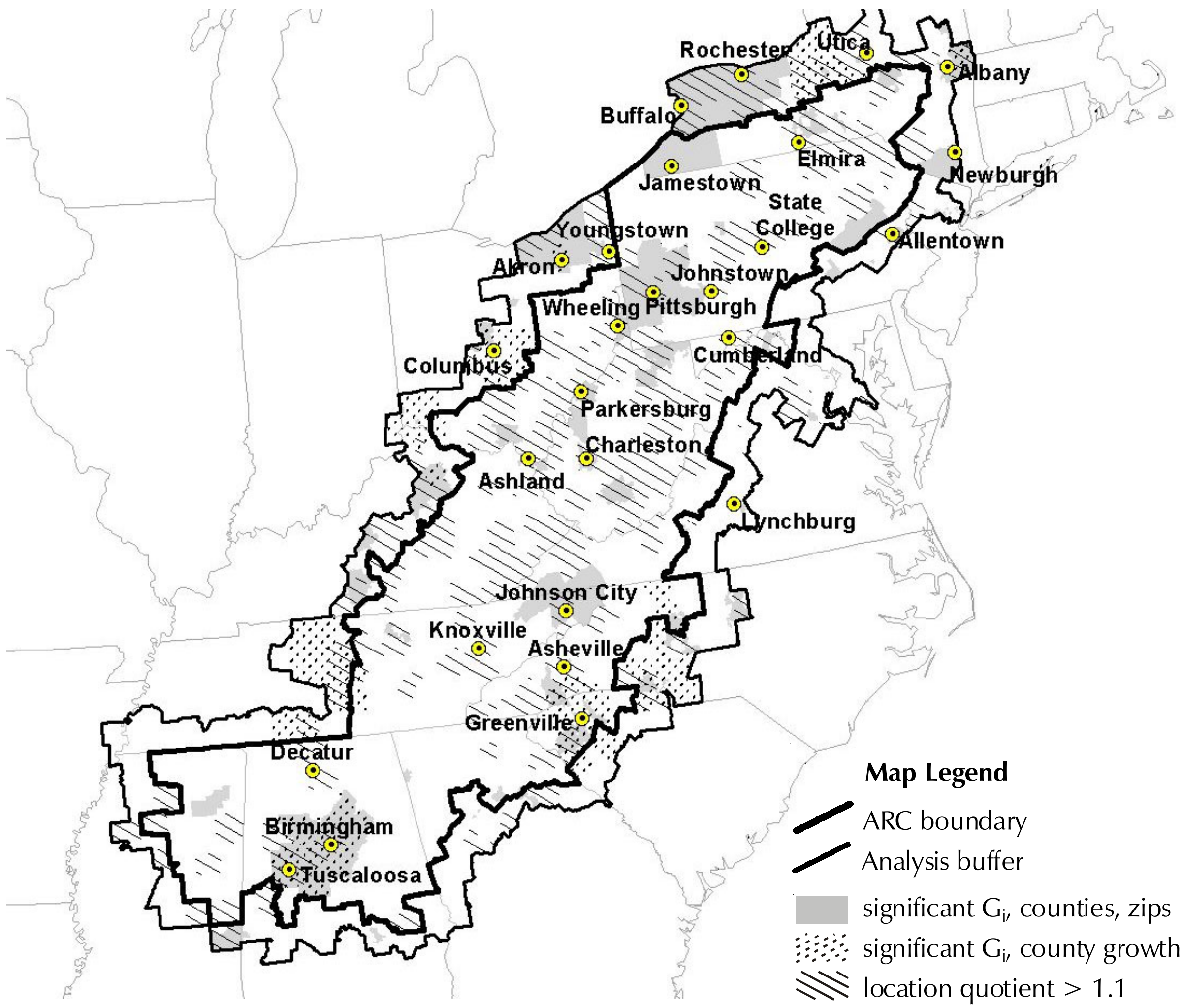


sectors into new groups that represent distinct value-chains, or groups of high-tech industries that are significant trading partners.

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



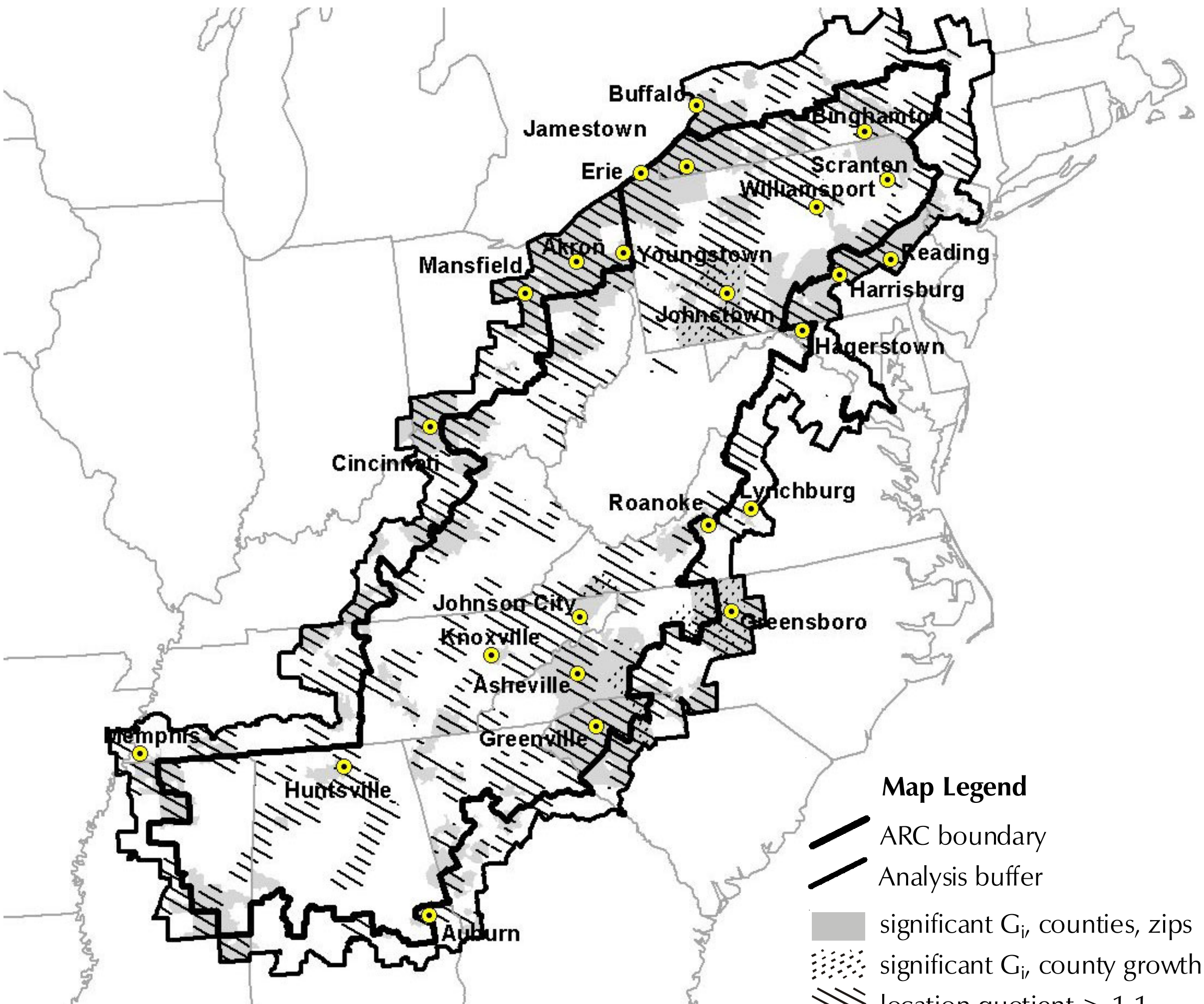
15. The technology value-chains are derived from a statistical analysis of national input-output data. Input-output data provide a useful characterization of trading patterns and general technological similarities among all U.S. industries, but with an emphasis on manufacturing. The value-chains are 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

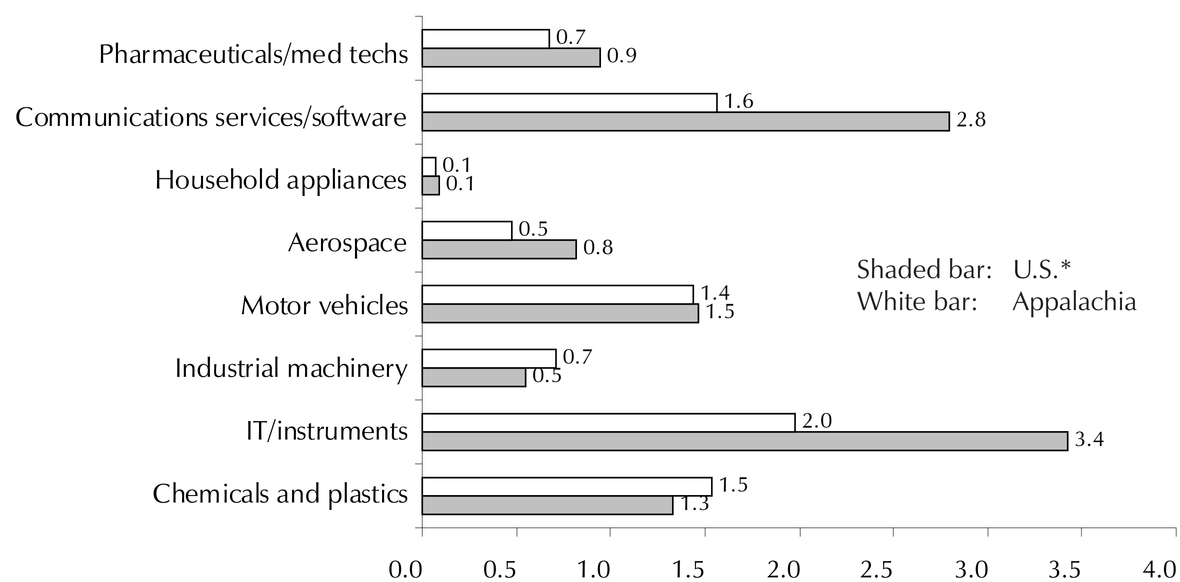
Source: U.S. Bureau of Labor Statistics, ES-202 files. *U.S. figures exclude Alaska, Hawaii, and Wyoming. Appalachia includes only the 406-county ARC region. Value-chains are not mututally exclusive and do not include all technology-intensive industries that make up the STI, MTI, and VTI sectors in Table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

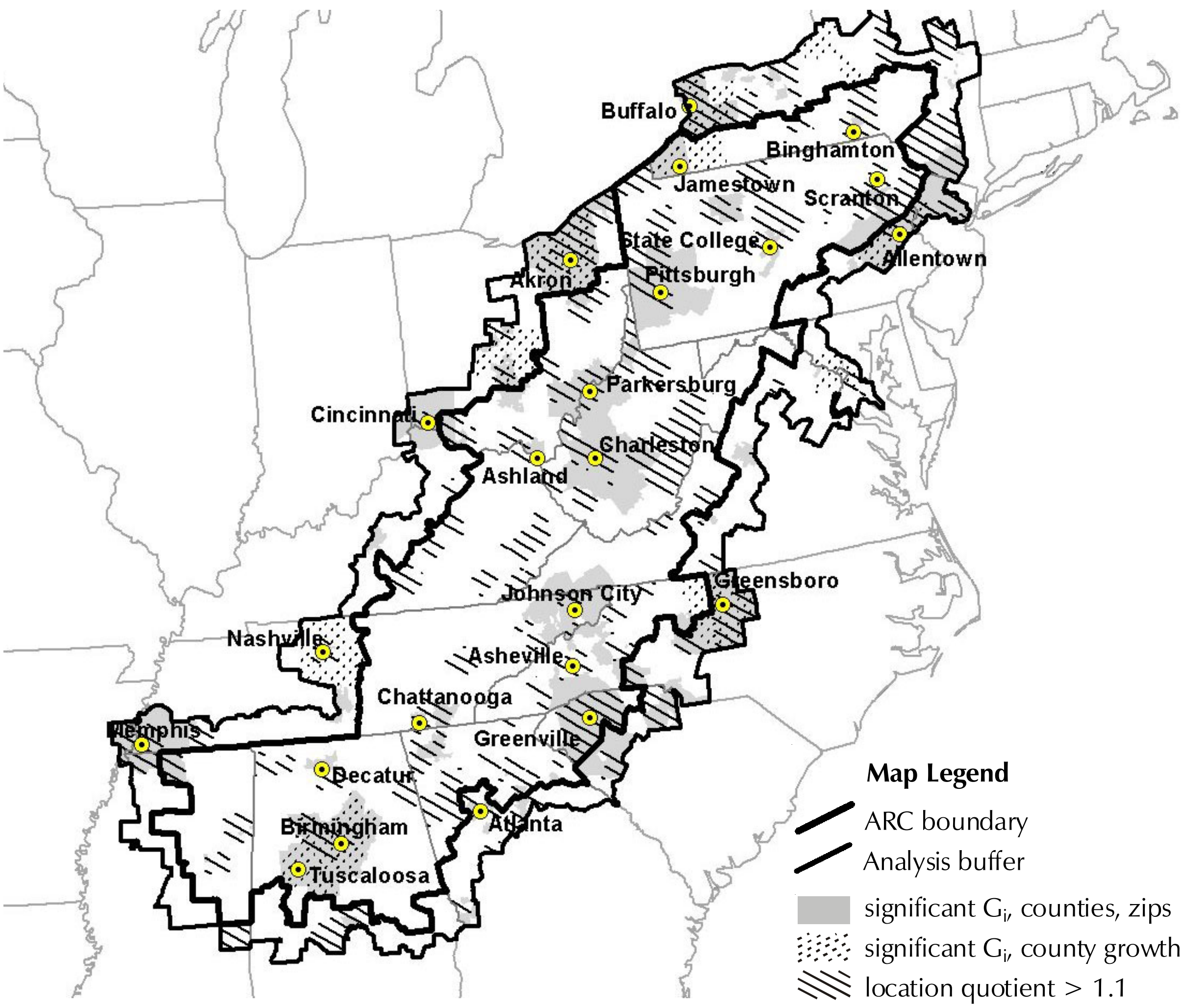


Figure 10

Spatial concentration: Motor vehicles value-chain

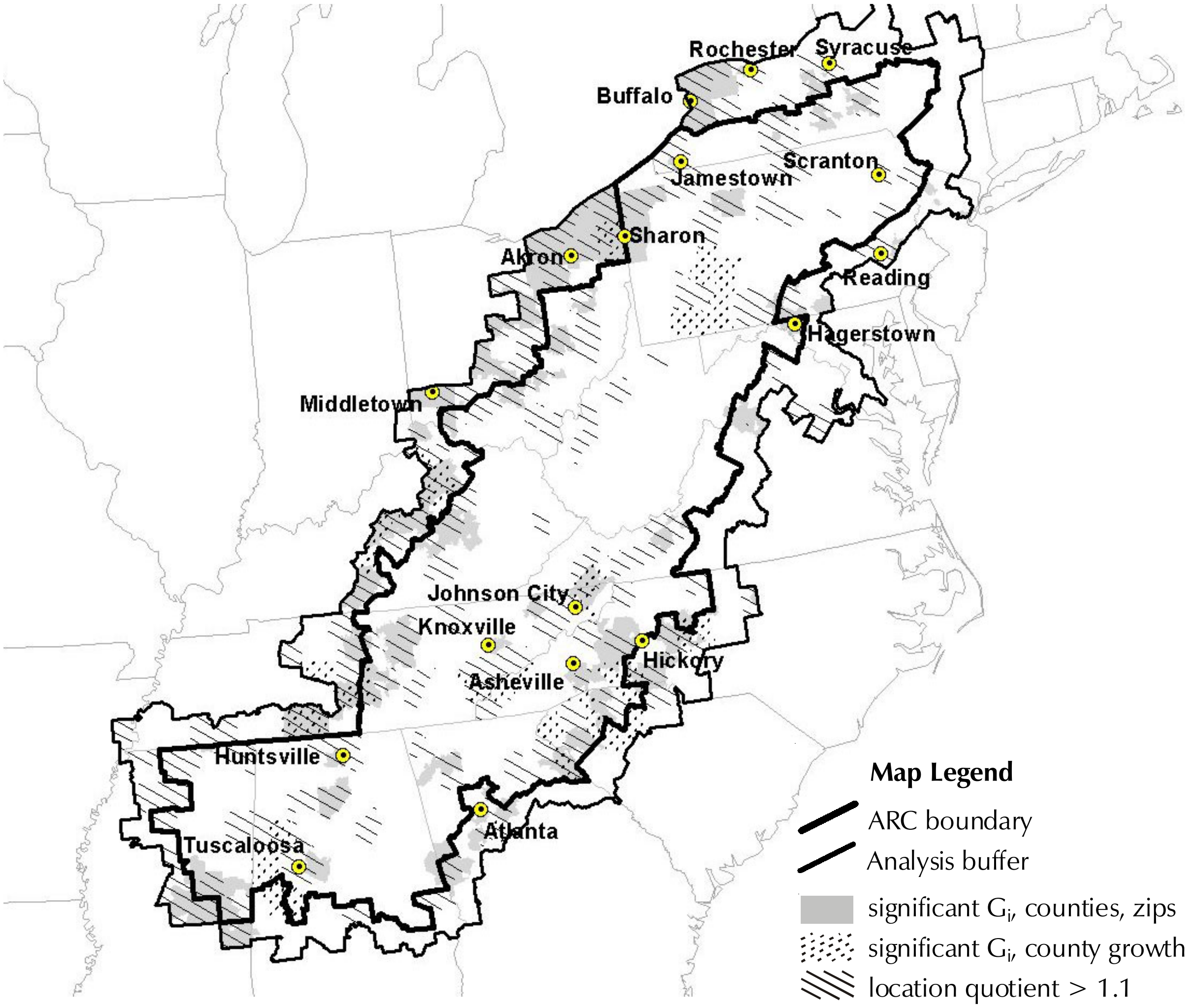


Figure 11

Spatial concentration: Industrial machinery value-chain

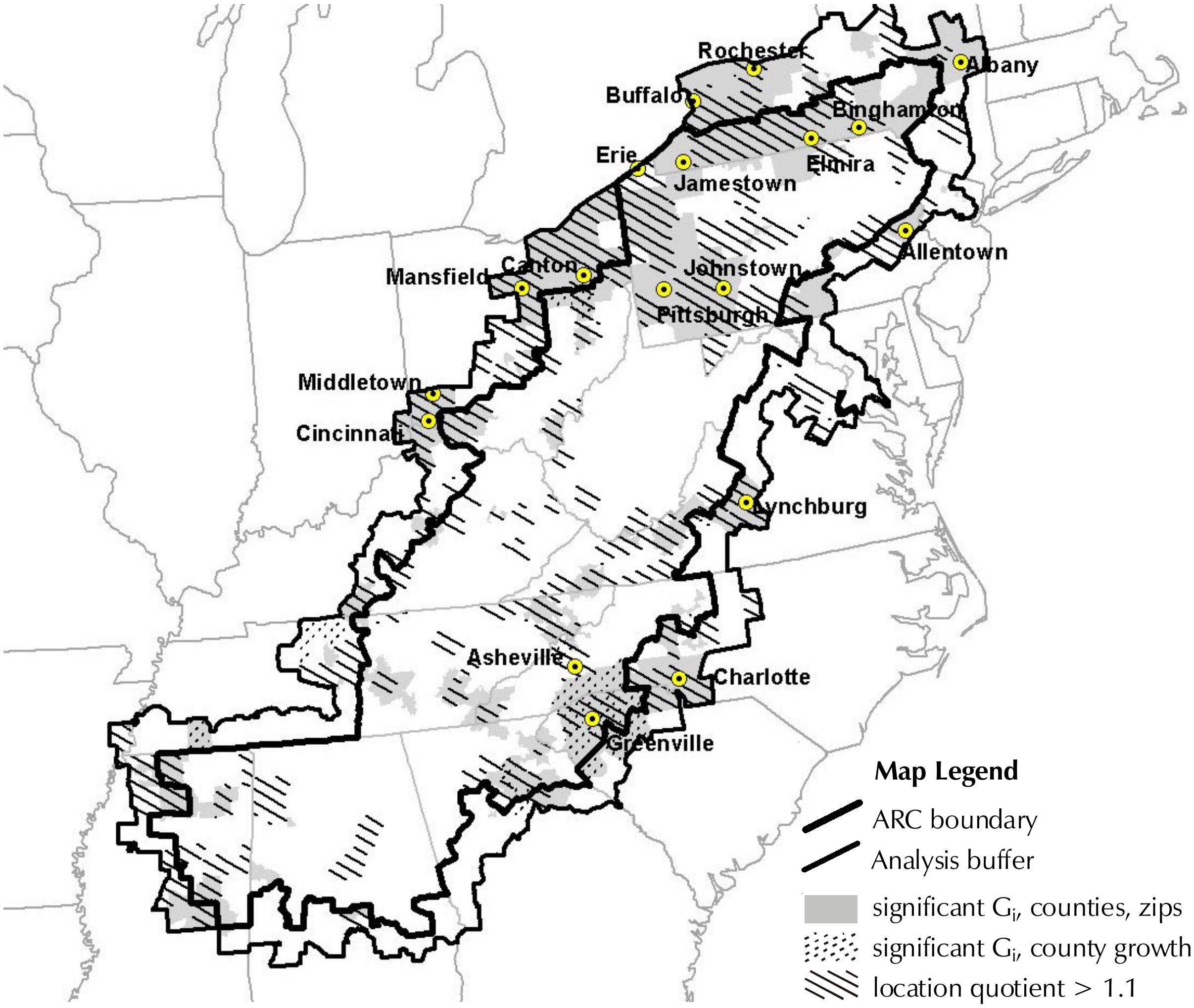


Figure 12

Spatial concentration: Information technology and instruments value-chain

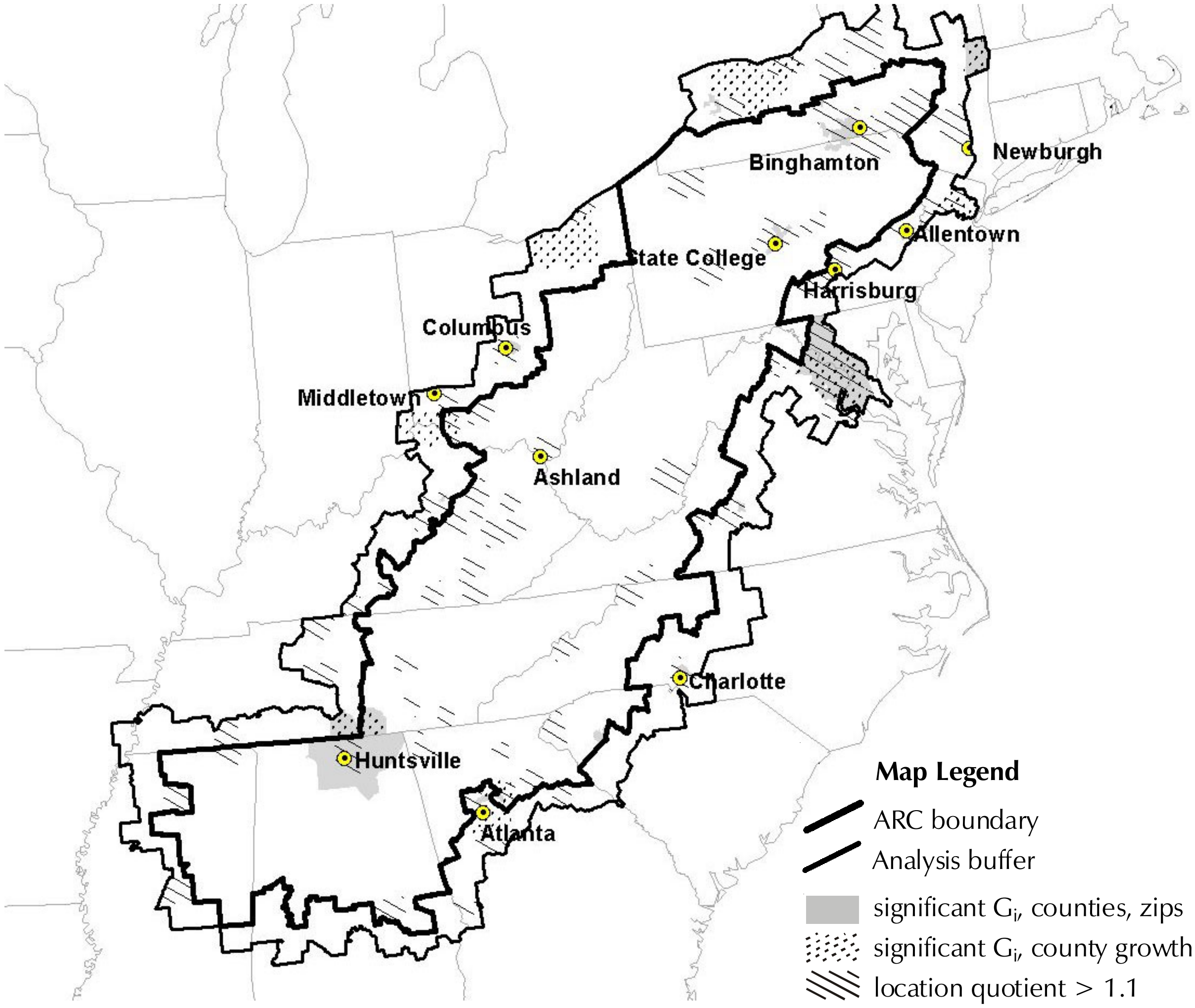


Figure 13

Spatial concentration: Communications services & software value-chain

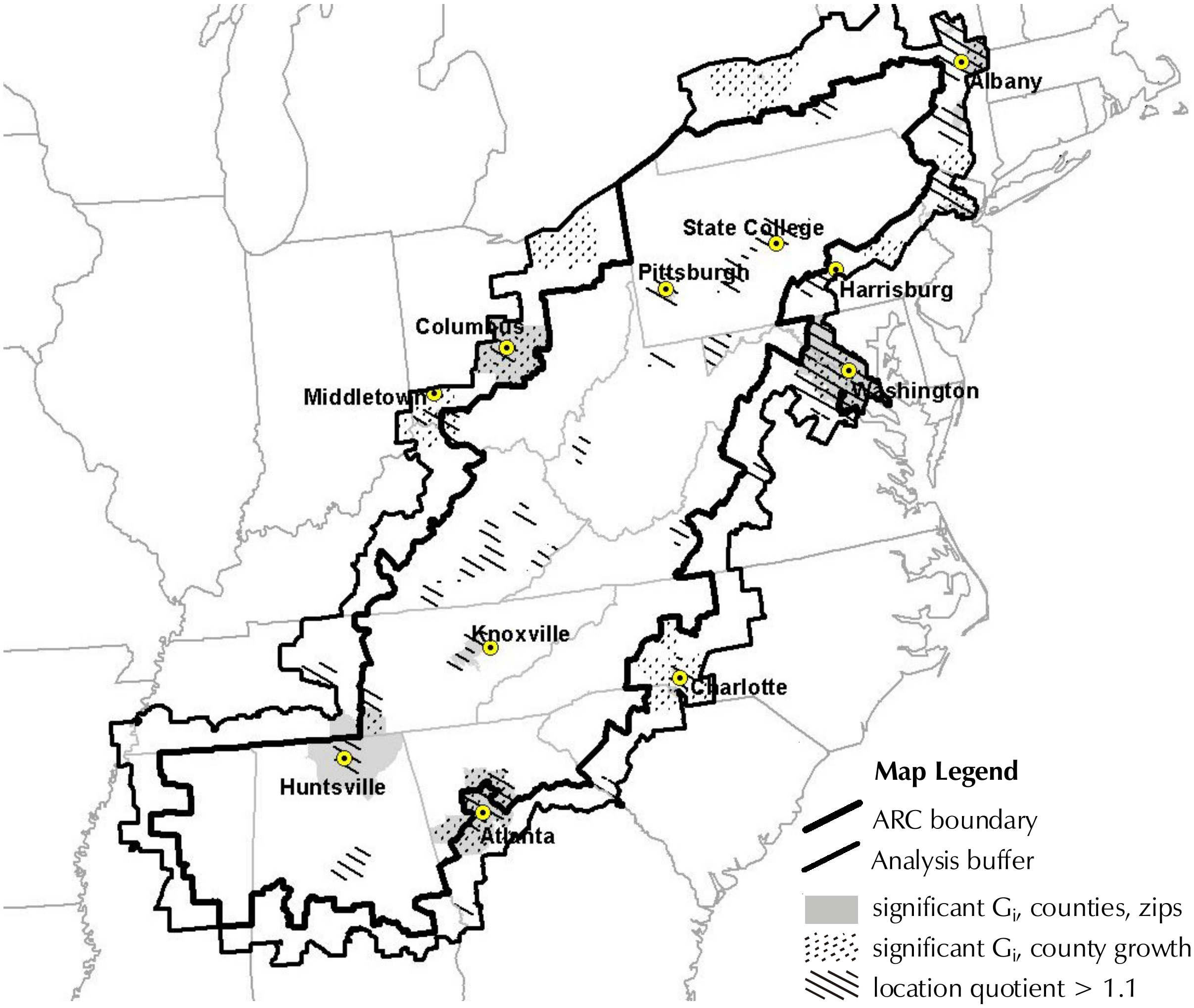


Figure 14

Spatial concentration: Aerospace value-chain

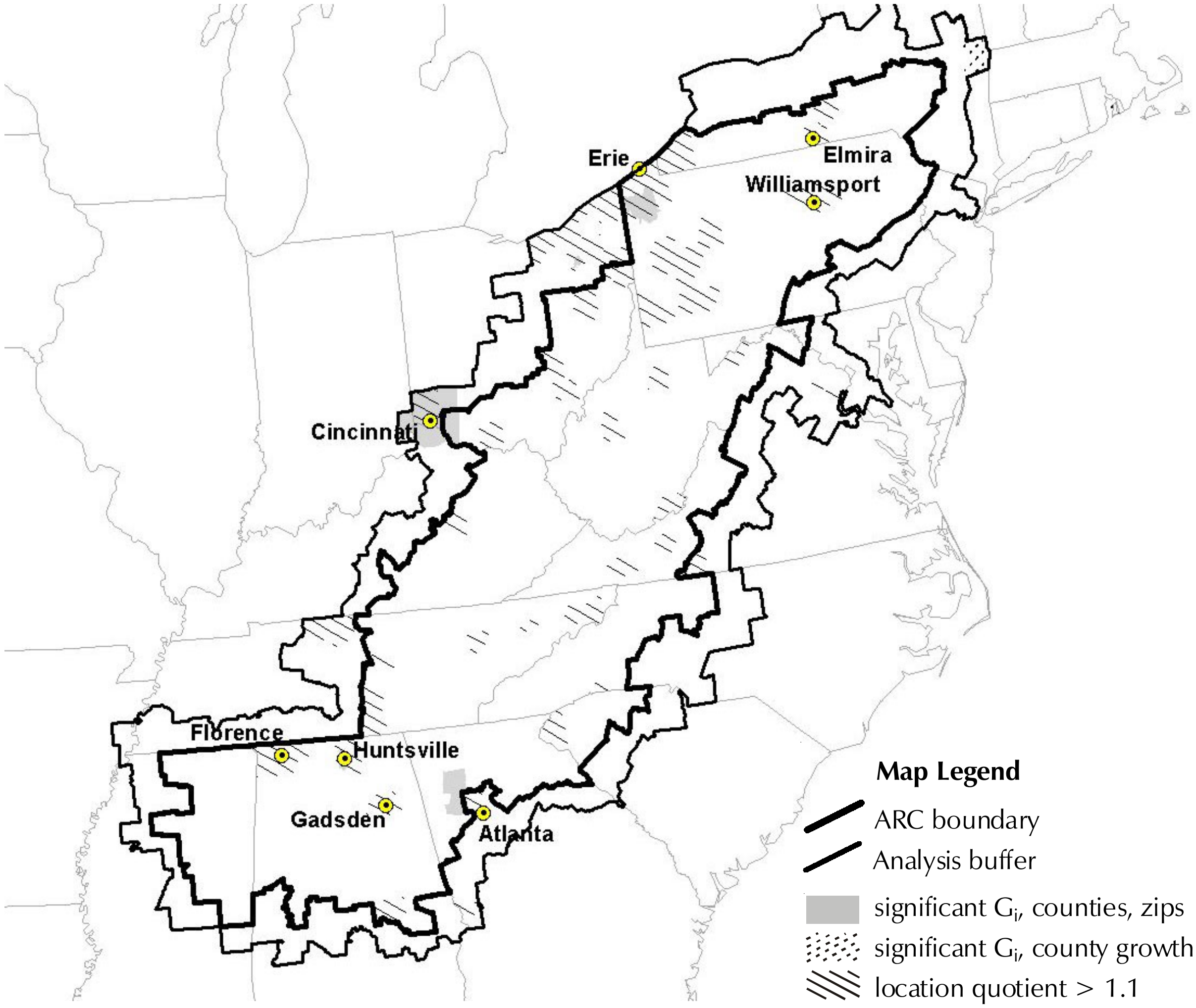


Figure 15

Spatial concentration: Household appliances value-chain

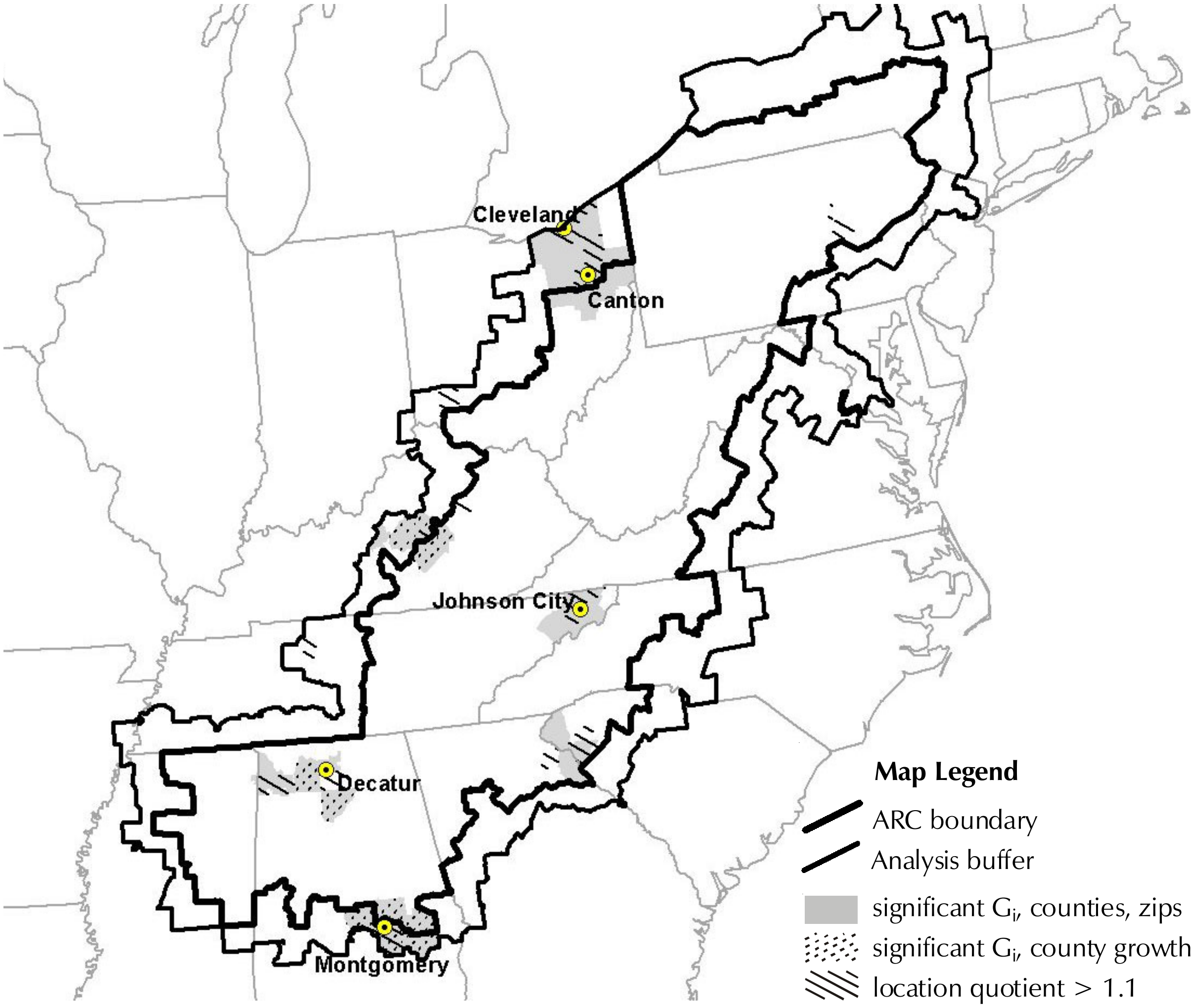
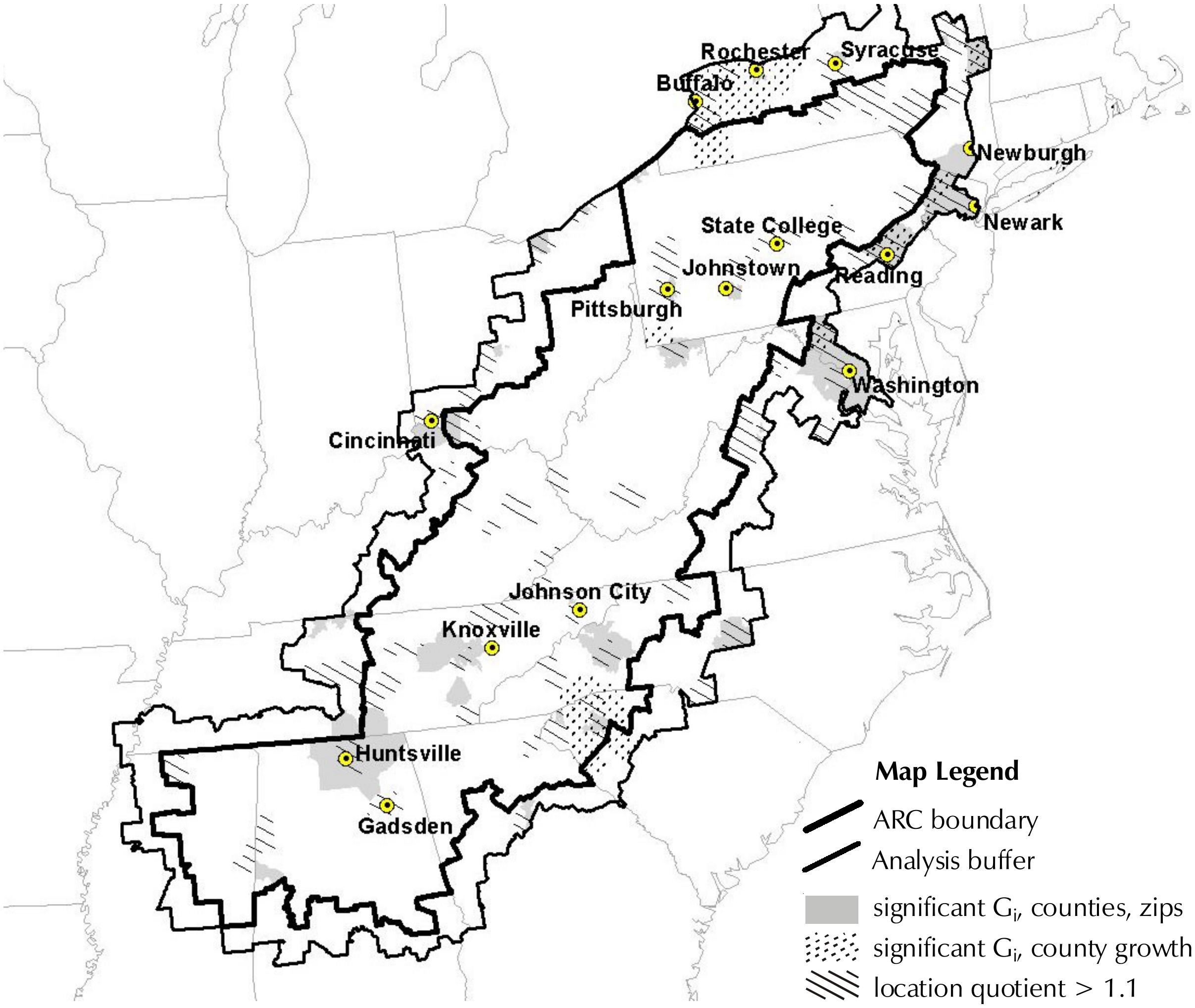


Figure 16

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

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.

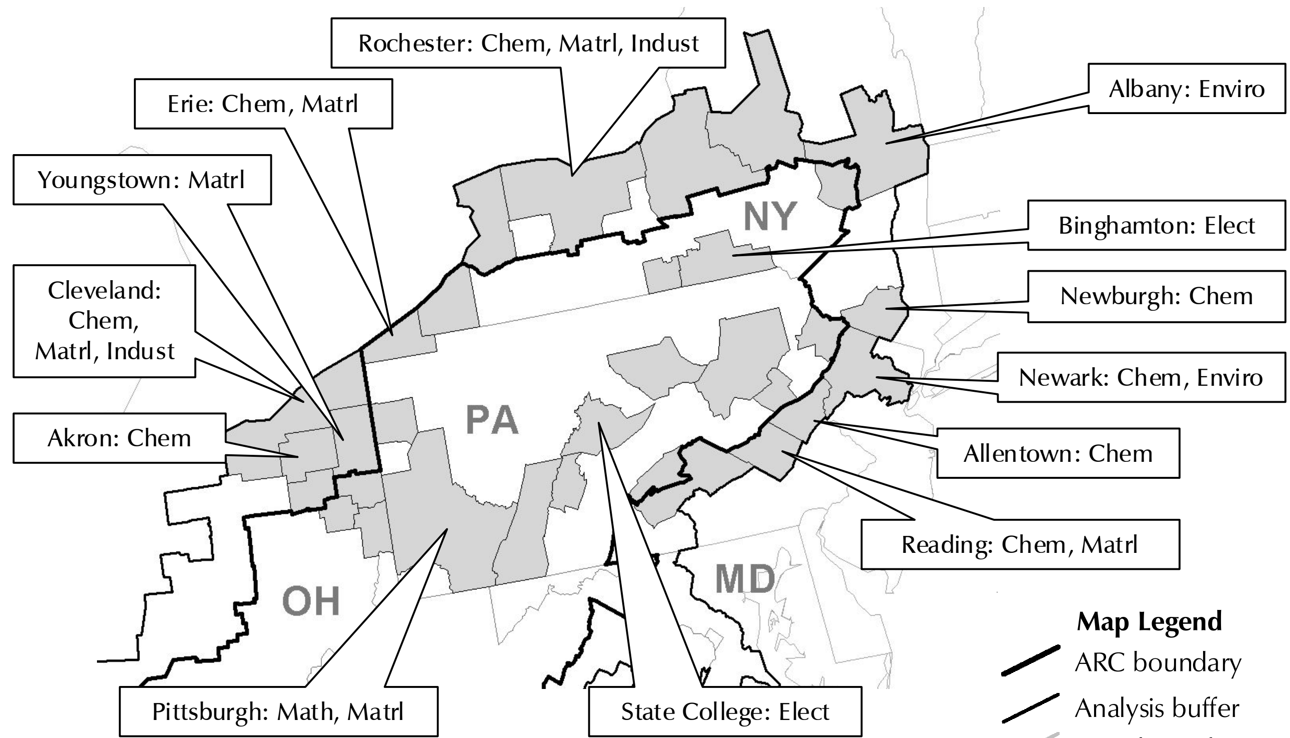
Table 6
Location quotients: Scientists, engineers and technicians, 1999

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

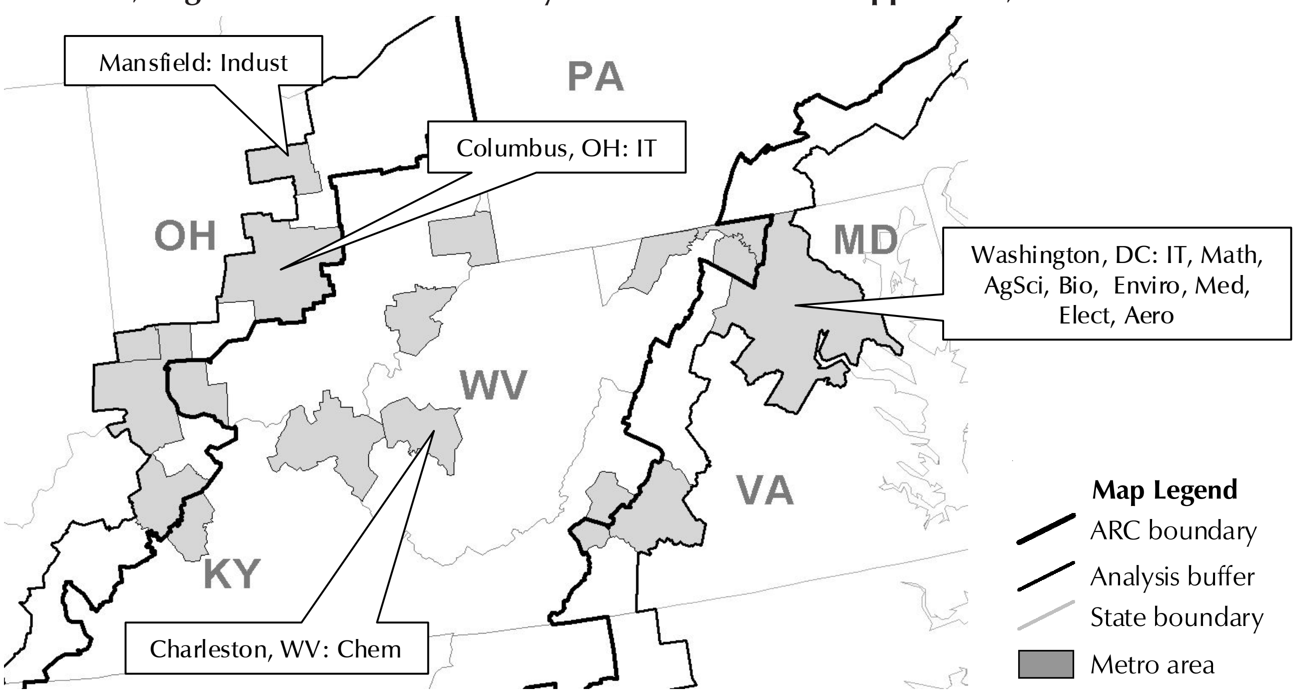
Scientists, engineers and technicians by metro area: Northern Appalachia, 1999



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.

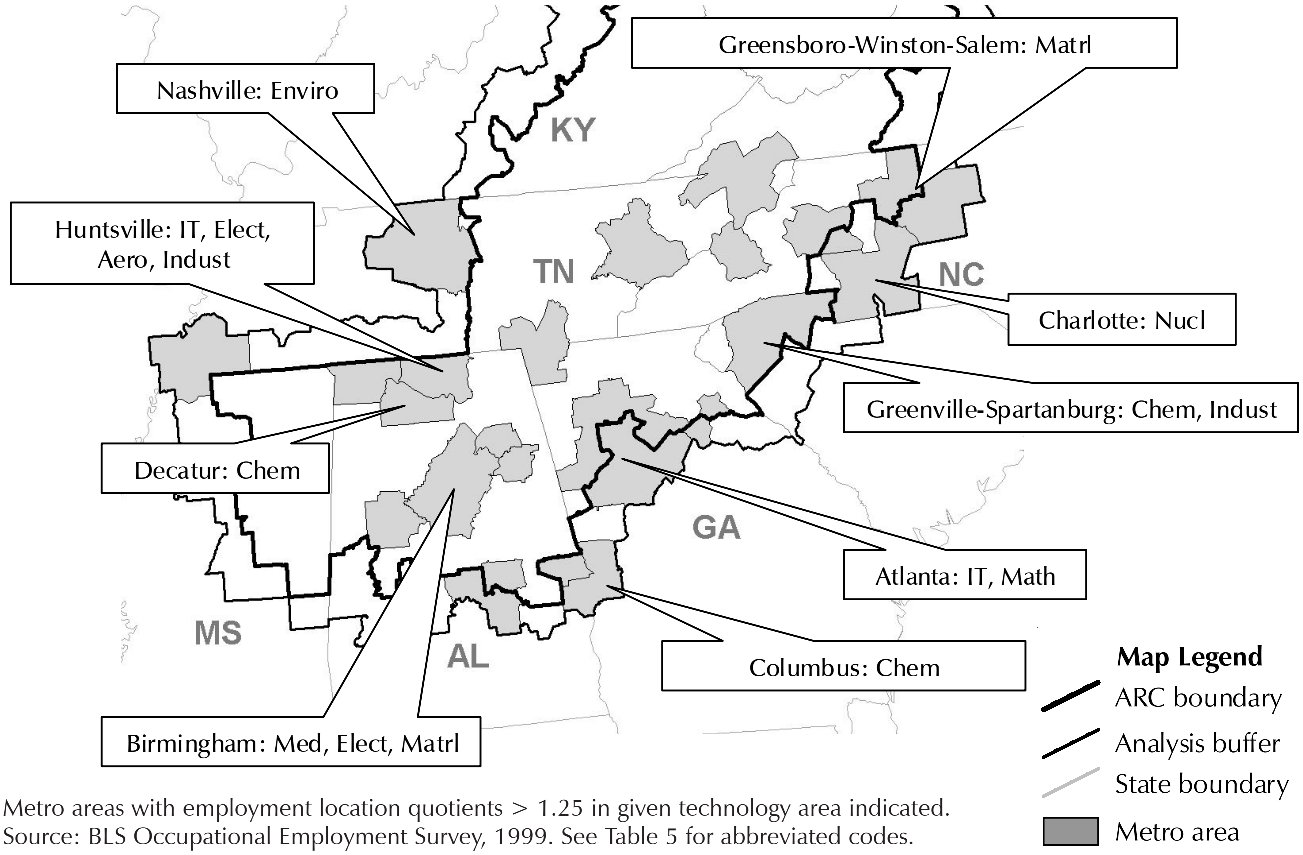
Figure 18

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.

---

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.