Regional Technology Assets and Opportunities:

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

Prepared for the
Appalachian Regional Commission

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August 2002

EXECUTIVE SUMMARY

Regional Technology Assets and Opportunities: The Geographic Clustering of High-Tech Industry, Science and Innovation in Appalachia

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]

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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.

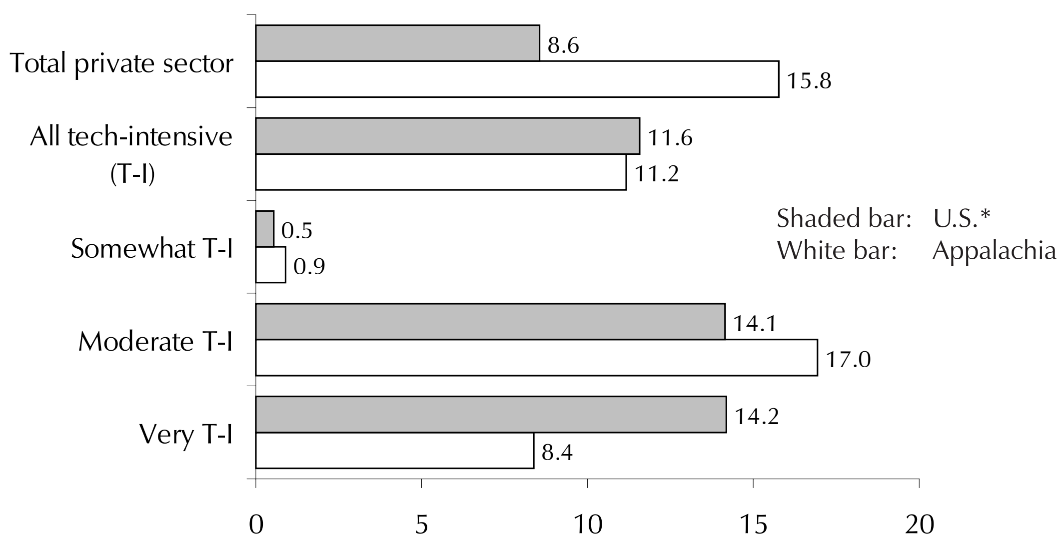
5. The data in Table 1 and Figures 1 and 2 are based on a classification of technology sectors developed by the North Carolina Employment Security Commission, which based its scheme on U.S. Bureau of Labor Statistics and National Science Foundation studies of the share of science and engineering workers 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.

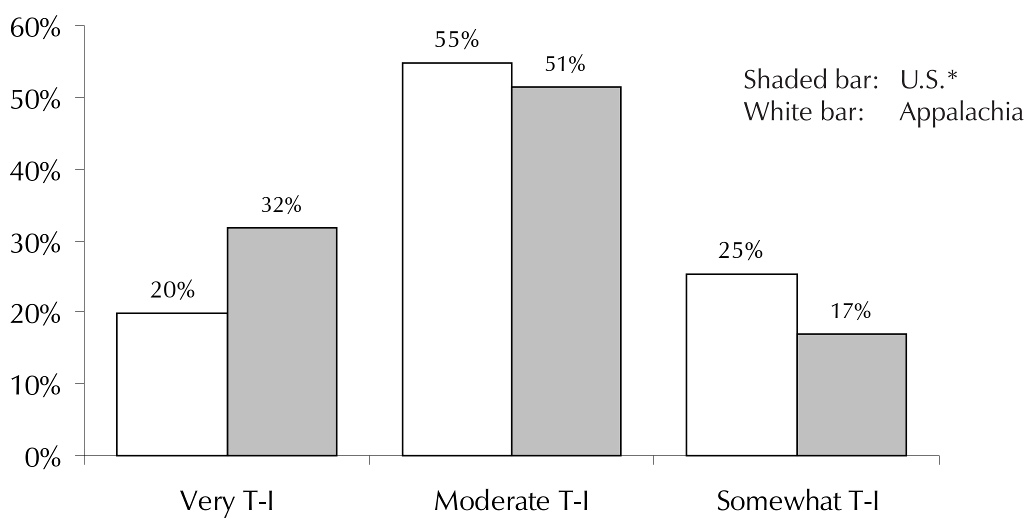
6. Employment in private universities is also not included.

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



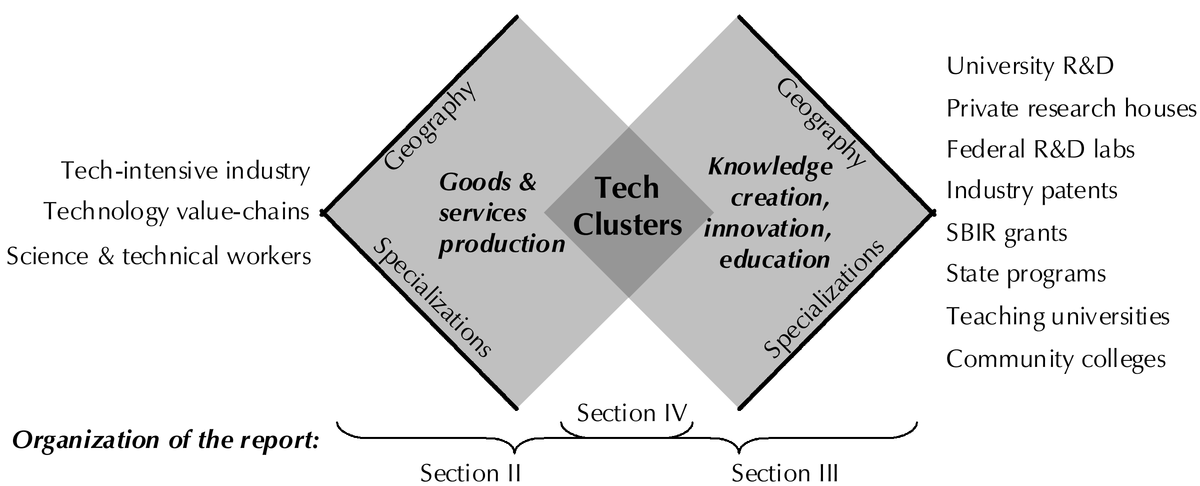
Source: U.S. Bureau of Labor Statistics. *Excludes WY, AK, & HI.

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



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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.