
Can Rural America Support a Knowledge Economy?

By Jason Henderson and Bridget Abraham

Knowledge has become the new premium fuel for economic growth in the 21st century. Knowledge fuels new ideas and innovations to boost productivity—and to create new products, new firms, new jobs, and new wealth. Some analysts estimate that knowledge-based activity accounts for half of the gross domestic product in Western industrialized countries. In the United States, knowledge-based industries paced gross domestic product (GDP) growth from 1991 to 2001, and their importance has accelerated since 1995.

In rural America, as elsewhere, a variety of factors make knowledge-based growth possible: high-skilled labor, colleges and universities, vibrant business networks, and infrastructure. Some rural communities are already leveraging these assets to transform their economy. Many other rural places, however, have yet to tap this rich economic potential.

This article analyzes the factors essential to rural knowledge-based activity in rural America. The first section defines knowledge-based economic activity, describes its growing importance in the U.S. economy, and identifies the regions of the country where it is concentrated. The

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second section uses empirical evidence to identify the factors that are essential to rural knowledge-based activity. The third section describes how some rural communities are leveraging these factors to build their own knowledge economy.

I. KNOWLEDGE: THE NEW ECONOMIC FUEL

Traditionally, economic growth was based on the physical resources and the products they produced. Today, knowledge powers the U.S. economy by generating new ideas and innovations that boost productivity and create new products.

What is knowledge-based economic activity?

Knowledge-based activities emerge from an intangible resource that enables workers to use existing facts and understandings to generate new ideas. These ideas produce innovations that lead to increased productivity, new products and services, and economic growth. In short, knowledge-based growth is derived from people's knowledge or ability to combine education, experience, and ingenuity to power growth.

Knowledge is often equated with information because both assets are intangible. Information, however, can be written down or outlined in a patent or process, making it easy to reproduce. Pieces of writing, artwork, music, movies, and datasets are information because they can be reproduced with the click of a button or the exchange of a CD. By contrast, the knowledge used to produce information is harder to codify or summarize on a piece of paper (Audretsch, Queau). Knowledge evolves and continuously combines varying pieces of information to meet changing needs.¹ For example, the information architects create in the form of blueprints can be easily reproduced, but the knowledge used to create them is difficult to replicate as it is embedded in the education, experience, and ingenuity of the architect. In addition, it takes knowledge to alter or transform information—in this case, altering blueprints or turning them into buildings. As a result, knowledge is considerably less tangible than information.

Knowledge is also different from information and other resources because it produces spillovers. Spillovers are benefits to people beyond those who possess the knowledge. Like other resources, knowledge gives a direct boost to the economic growth of people, firms, and communities that have higher stocks of knowledge. But knowledge also provides indirect benefits by boosting the knowledge levels of other people, firms, and communities.² Returning to our example, an architect can produce spillovers by interacting with other local architects and boosting their knowledge levels, such as through business mentoring.

Because of spillovers, the full potential of knowledge as the fuel for economic growth expands with the increasing interactions of people. Knowledge is enhanced through personal interactions, observation, action, and experience. It stimulates economic growth when shared among networks of people, businesses, and institutions (Maleck). Firms tend to cluster near other related firms to build these knowledge-sharing networks (Rosenfeld).

These interactions, or spillovers, often turn knowledge-based activity into entrepreneurship. Both activities focus on transforming new ideas into innovations that produce economic growth. Entrepreneurship is “the process of uncovering or developing an opportunity to create value through innovation” (Kauffman Center). Entrepreneurs are responsible for transforming knowledge into new technologies, products, and services, and then bringing new products and ideas to the marketplace each year.

The importance of knowledge to U.S. growth

The intangible nature of knowledge—that special quality which makes it unique—also makes it difficult to measure. How does one measure the ability to combine education, experience, and ingenuity to boost productivity or create new products? While direct measures still do not exist, economists have used a variety of techniques to measure knowledge activity indirectly (OECD 1996).

Two common indirect measures of knowledge-based activity focus on occupations. One measure is simply the number of people in occupations that use high levels of knowledge to perform their tasks. The Bureau of Labor Statistics measures the difficulty, complexity, and

knowledge of U.S. occupations in an occupational criteria scale.³ According to this scale, knowledge occupations are defined as management, professional, and technical occupations.

A second common measure of knowledge-based activity is based on occupations at the industry level. Industries are classified into high-, medium-, or low-knowledge categories, according to the share of knowledge occupations in the industry.⁴ Industries are classified as high-knowledge if knowledge occupations account for more than 40 percent of the occupations. (The box on the next page gives a detailed description of the measures of knowledge-based activity.)

According to both measures, knowledge-based activity has paced recent U.S. economic growth. At the occupation level, growth in knowledge occupations rose more than 2 percent annually from 1991 to 2001, compared with 0.6 percent for other occupations.⁵ High-knowledge occupations accounted for a third of all occupations in 2000, after accounting for a fourth of all occupations in 1980.

High-knowledge industries helped keep the economic expansion of the 1990s strong. From 1991 to 2001, U.S. gross domestic product in high-knowledge industries rose 4.4 percent per year—faster than all other industries, and the gap is widening (Table 1).

Such strong growth in the output of high-knowledge industries has translated into rapid gains in the number of establishments and employment.⁶ From 1990 to 1997, total establishments in high-knowledge industries rose 4.5 percent annually (Table 1). During the same time, total employment in high-knowledge industries rose 3.8 percent.⁷

The jobs knowledge-based activity has provided are typically high-wage jobs. In 2001, the average annual wage in knowledge occupations was more than \$50,000, double the average annual wage in other occupations. And from 1990 to 1997 the wage gap between high- and low-knowledge industries widened from \$7,500 to \$10,300 (Table 1).

Where is the U.S. knowledge economy?

While knowledge-based activity is pacing U.S. economic growth, not all parts of the country have shared equally in its wealth. Metro areas tend to have larger concentrations than their rural counterparts, and the concentration is highly varied.⁸

MEASURING KNOWLEDGE-BASED ACTIVITY

Given the difficulty in codifying knowledge, knowledge-based activity is, in general, difficult to measure. Researchers have developed multiple ways to identify and measure knowledge-based activity. Some view knowledge as an input and measure knowledge based on an occupation's human capital requirements. Others assume that knowledge-based activity is an output that arises at the sector level because knowledge-based growth is driven by spillovers. See OECD (1996) for a more detailed discussion of knowledge-based growth measures.

An input measure of knowledge-based activity

The Bureau of Labor Statistics measures the difficulty and complexity of occupations based on an occupational leveling criteria scale. In the scale, an occupation is graded and awarded points on ten individual factors: knowledge, supervision received, guidelines, complexity, scope and effect, personal contacts, purpose of contacts, physical demands, work environment, and supervisory duties. For each occupation, the points from all the factors are totaled. The point total is then used to measure the occupation against the 15 level occupational leveling criteria scale.

In the occupational leveling criteria, knowledge is the highest weighted individual factor. For example, an occupation could receive a maximum of 1,850 points for its knowledge factor score, three times the number of points that can be awarded for any other factor. The knowledge factor dominates most other factors in the criteria making the occupational leveling criteria scale an appropriate approximation of an occupation's knowledge level.

In this article, high-knowledge occupations were identified as the managerial, professional, and technical occupation groups. These occupational groups had some occupations that ranked a ten or higher on the occupational leveling criteria. For example, civil engineering occupations ranked between 5 and

14 on the occupational leveling criteria scale, while child care workers ranked between 1 and 8 on the scale. Civil engineers were classified as high-knowledge because some of the occupations were 10 or higher, while child care workers were not classified as high-knowledge.

An output-based measure of knowledge-based activity

Knowledge-based activity has also been measured as an output. Typical output-based methods identify certain industries sectors as more or less knowledge intensive. For example, Beck classified U.S. industries into high-, moderate-, and low-knowledge categories based on the share of knowledge occupations employed in the industry. Knowledge occupations were identified as managerial, professional, and technical workers. Industries were classified as high-knowledge if they have more than 40 percent of the occupations in knowledge occupations, moderate-knowledge if 20 to 40 percent of their occupations were knowledge occupations and low knowledge if less than 20 percent of their occupations were in knowledge occupations. The following table lists high-knowledge industries identified by Beck and used in this article.

HIGH-KNOWLEDGE INDUSTRIES

Drugs	Motion pictures
Computer and office equipment	Health services (excluding nursing and personal care facilities)
Communications equipment	Legal services
Guided missiles, space vehicles and parts	Educational services
Search and navigation equipment	(excluding libraries)
Measuring and controlling devices	Individual and family social services
Radio and television broadcasting	Child daycare services
Funeral service and crematory	Museums, art galleries, botanical and zoological gardens
Advertising	Membership organizations
Consumer credit agencies	Engineering and management services
Computer programming and data processing	

Source: Beck (1992) *Shifting Gears: Thriving in the New Economy*

Table 1
ECONOMIC ACTIVITY BY INDUSTRY KNOWLEDGE CATEGORY

Industry Knowledge Category	GDP growth (annual percent change)		Establishment growth (annual percent change)		Employment growth (annual percent change)		Share of establishments* (percent)		Share of employment* (percent)		Average annual wage (thousand dollars)	
	1991-2001	1995-2001	1990-1997	1990-1997	1990-1997	1990-1997	1990	1997	1990	1997	1990	1997
High	4.4	5.9	4.5	4.5	3.8	23.4	21.3	23.4	21.1	23.1	25.9	35.0
Moderate	4.0	4.2	2.5	2.5	1.7	21.5	20.2	21.5	27.1	27.5	25.4	31.4
Low	3.6	4.0	1.5	1.5	1.3	55.1	58.5	55.1	51.7	49.5	18.4	23.0
U.S. total	3.9	4.4	2.4	2.4	2.0	100.0	100.0	100.0	100.0	100.0	21.9	28.1

*Shares may not sum to 100 percent due to rounding error.

Notes: Establishment, employment, and wage calculations based on County Business Patterns data. GDP calculations based on U.S. Dept. of Commerce data. Industry categories based on Beck's knowledge ratio.

Figure 1
SHARE OF OCCUPATIONS IN KNOWLEDGE
OCCUPATIONS

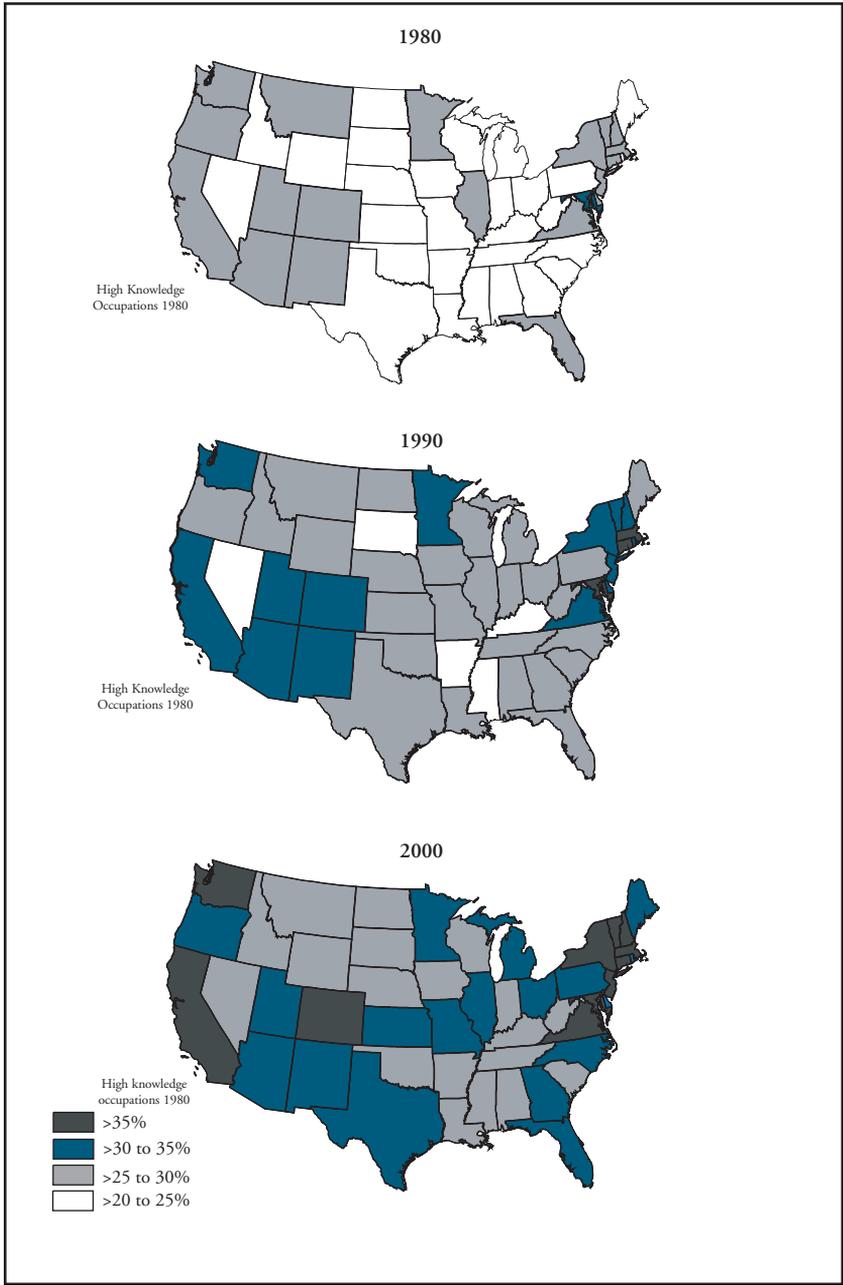
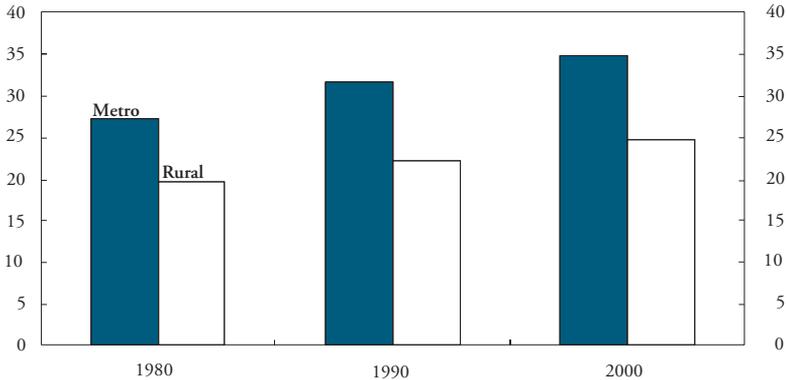


Chart 1

CONCENTRATION OF HIGH KNOWLEDGE ACTIVITY

Share of occupations in knowledge occupations



Note: Calculations based on U.S. Census data and exclude Alaska and Hawaii counties.

From 1980 to 2000, the share of high-knowledge occupations rose in every state, but growth was strong in only several regions (Figure 1). The Mid-Atlantic and New England states led all states, with the Far West and Rocky Mountain regions not far behind. The Southeast and Southwest regions had a lower concentration of knowledge industries, but these regions experienced some of the fastest growth in these industries, trailing only the Rocky Mountain region in their growth rate.

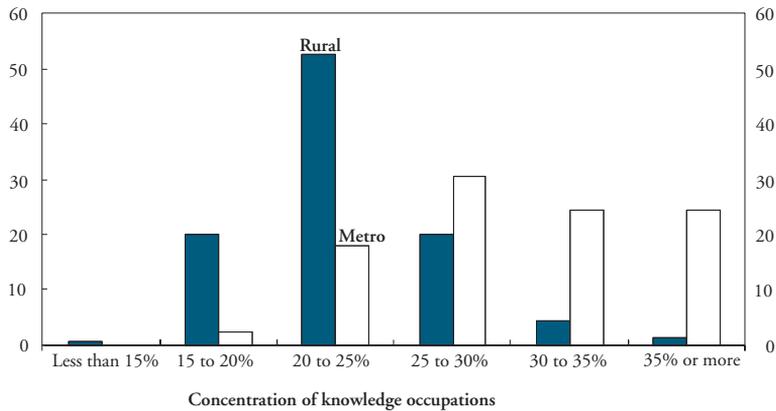
Within these regions, the concentration of knowledge occupations was uneven. In general, nonmetro, or rural, places trailed their metro counterparts in the concentration of high-knowledge occupations. Roughly a fourth of all occupations in rural areas are considered high-knowledge, compared with more than a third in metro areas (Chart 1).⁹ Even though 95 percent of all rural counties saw a rise in high-knowledge occupations from 1980 to 2000, the gap between rural and metro areas widened.

The widening gap between metro and rural areas reflects the scattered distribution of rural knowledge occupations. In roughly one in every four rural counties in 2000, high-knowledge occupations accounted for less than 20 percent of all occupations (Chart 2). That low concentration compares with one in every five metro counties. Still, it is important to recognize that a handful of rural communities have

Chart 2

KNOWLEDGE OCCUPATIONS IN RURAL AND METRO COUNTIES, 2000

Percent of counties



Note: Calculations based on U.S. Census data and exclude Alaska and Hawaii counties.

developed a significant concentration of high-knowledge occupations. In about 5 percent of rural counties, high-knowledge occupations accounted for more than 30 percent of all occupations.

II. WHAT FACTORS SUPPORT KNOWLEDGE ACTIVITIES IN RURAL AMERICA?

Given the uneven distribution of high-knowledge occupations throughout the countryside, rural stakeholders are asking why some rural places have developed higher concentrations of high-knowledge occupations than others. Many factors influence the location of high-knowledge occupations, ranging from the availability of high-skilled labor to the size and remoteness of rural communities.

This article uses a regression framework to identify the characteristics of rural counties that are most often tied to a concentration of high-knowledge occupations.¹⁰ The empirical model identifies the various county characteristics related to the county's share of high-knowledge occupations in 2000.¹¹ (The appendix describes the regression model in detail.)

A *high-quality labor force* is a major factor in building a knowledge economy. Knowledge occupations require people with higher skill levels. Not surprisingly, places with larger concentrations of high-skilled labor are more attractive to knowledge-based firms. Moreover, people with high-skill levels are more likely to generate innovations and start knowledge-based firms. In a study of innovation across U.S. cities, patent rates were highest in cities with higher levels of educational attainment. In fact, San Jose, California, had the highest patent rate in 1992 and the second-highest level of educational attainment; one-third of its workers had earned a university degree (Audretsch).

Rural counties with higher concentrations of high-skilled labor were found to have higher concentrations of high-knowledge occupations. In rural counties, a 1 percent increase in the educational attainment of a bachelor's degree translated into a 0.84 percent rise in the concentration of high-knowledge occupations.¹²

College or universities are an important factor in the location of knowledge-based activity for several reasons. First, of course, a local educational institution provides the education for a higher-skilled labor force. But, second, and perhaps just as important, colleges and universities also generate research and development that can lead to new commercial products, new firms, and new jobs. University research and development is a key ingredient in the innovations of small firms (Acs and others 1994). In Finland, the local university was a key catalyst in helping Nokia transform itself from a paper mill to one of the world's leading cell phone and technology companies (Arnal and others). Indeed, rural counties with a college or university had concentrations of high-knowledge occupations 0.92 percent higher than other counties.^{13, 14}

Local amenities that enhance the quality of life are thought to have a strong influence on knowledge-based growth. Natural amenities are commonly associated with rural places. Scenic rural places have higher levels of economic, population, and income growth (Deller and others). Places with higher natural amenities were also found to have higher levels of high-tech industries, a subset of high-knowledge industries (Goetz and Rupasingha).¹⁵ For example, an entrepreneur located his computer programming business in Wiscasset, Maine (pop. 1,200), to be near the ocean (Beyers and Lindahl).

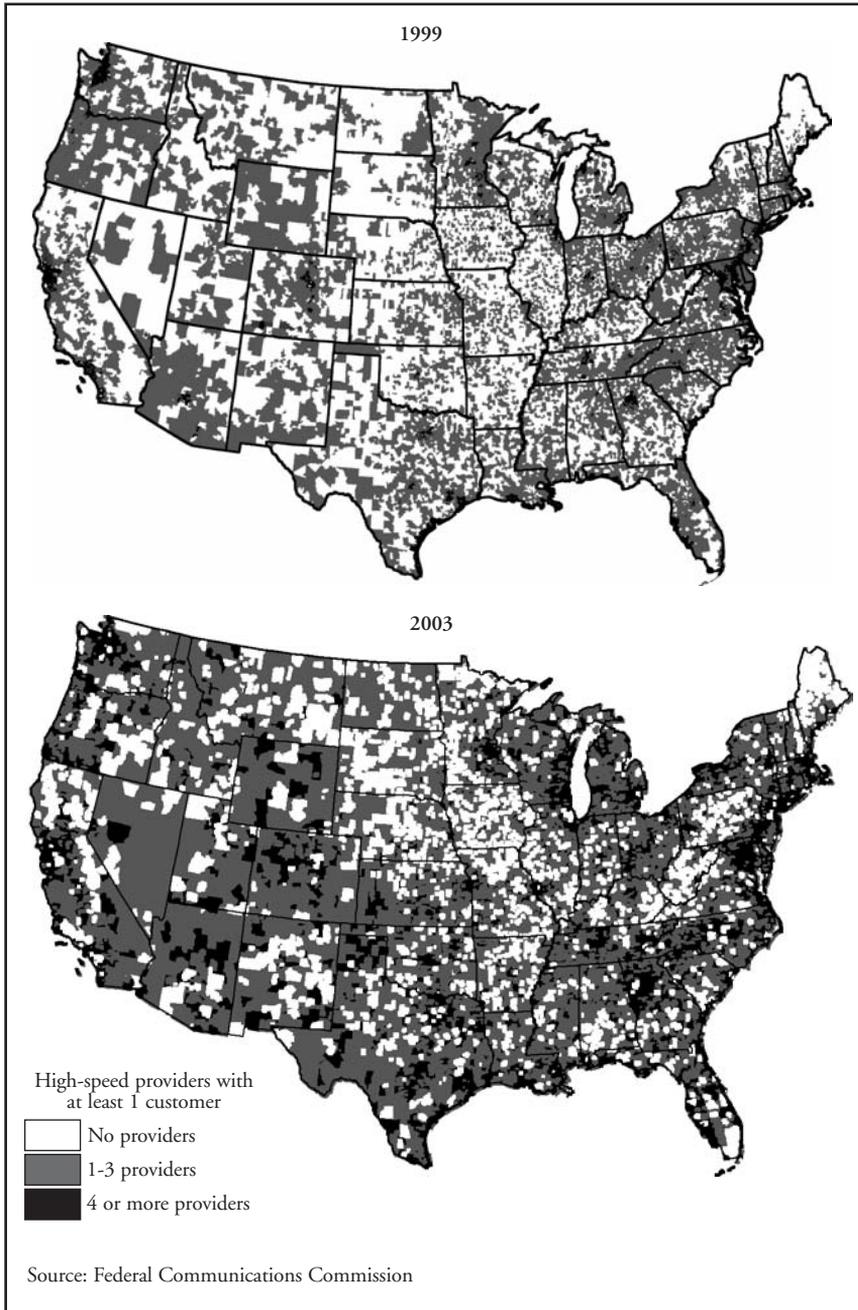
Natural amenities appear to be an important factor in the concentration of rural knowledge-based activity. Rural counties with higher levels of natural amenities associated with topography and water had higher shares of high-knowledge occupations. However, weather factors, which include temperature, humidity, and sunny days, were not found to be related to the share of high-knowledge workers.

Infrastructure, such as interstates, has traditionally influenced the location of economic activity. From 1990 to 2000, employment in Nebraska surged 22.5 percent in rural counties with an interstate, compared with 10.2 percent in counties without an interstate. Transportation infrastructure provides increased access to markets and reduces transaction costs for physical goods. Thus, interstates provide increased opportunities to network, connect, and share knowledge with firms in other regions or locations. Knowledge-based activities, however, are less sensitive to traditional infrastructure. In fact, the share of high-knowledge occupations in rural counties was not found to be significantly related to the presence of an interstate.¹⁶

New forms of infrastructure, however, such as broadband access, may be critical. Broadband allows knowledge workers to tap knowledge, information, and markets in other parts of the world. Broadband access has only begun to penetrate into many rural places (Figure 2). In 1999, about 18,000 zip code areas had broadband access with only 3,023 areas served by more than three carriers. By 2003, access had reached more than 27,000 zip code areas with more than 13,000 areas having more than three carriers. The empirical analysis, however, could not isolate this factor because of data limitations. It is simply too soon to tell how dramatically growth in broadband access will influence knowledge-based activity. One sign of influence would be the emergence of some knowledge-based clusters among broadband corridors in rural places.

The *size* of rural places is understandably an important factor in the rural knowledge economy. Rural places with larger economies offer more potential for personal and firm interactions. These interactions can reduce the search costs for businesses seeking knowledge and information in two ways.¹⁷ First, larger economies have more firms, allowing

Figure 2
HIGH-SPEED INTERNET COVERAGE BY ZIP CODE



for easier communication and greater potential for knowledge spillovers (Glaeser and others). Clusters of firms in knowledge-rich locations foster more innovations among firms (Beaudry and Breschi).

Of course, knowledge breeds knowledge. Rural counties in regions with an established cluster of knowledge activity had higher concentrations of knowledge occupations. The concentration of knowledge occupations was 0.30 percent higher if the share of knowledge occupations within 200 km (roughly 125 miles) was 1 percent higher.¹⁸ Rural counties with larger numbers of high-knowledge establishments in 1990 had higher concentrations of high-knowledge occupations in 2000. For every 100 high-knowledge establishments in 1990, the share of high-knowledge occupations in 2000 rose 0.46 percent.

Second, larger and more diverse economies result in larger knowledge pools that improve knowledge transfer and reduce the cost of knowledge acquisition. In general, the size of rural places limits the interactions needed for the sharing of knowledge. However, rural communities with larger and more diverse economies should provide larger pools of knowledge and be more supportive of knowledge-based activity.

Rural counties with larger towns had higher concentrations of knowledge occupations. If a rural county contained a town of greater than 10,000 people, the share of high-knowledge occupations rose 0.33 percent. Even if the county did not contain a large town, the share of high-knowledge occupations was higher in counties with higher population densities: 1.14 percent higher for every 100 people per square mile.

The *remoteness* of rural places limits the ability of rural people to obtain knowledge that exists in other communities. Rural businesses in remote locations must overcome a larger distance to tap into knowledge pools in more distant locations. Advanced communications technologies, such as the Internet, however, may reduce the impact of remoteness on rural knowledge-based growth. For example, the owner of a computer programming firm relocated to Akron, Colorado (pop. 1,174), because the information highway made location irrelevant (Beyers and Lindahl).

In fact, remoteness was found to be less of a challenge in stimulating knowledge-based activity than other factors. The proximity of a county to a metro area was not found to be important to knowledge-based activity. After controlling for other factors, counties adjacent to a metro area did not have higher shares of high-knowledge occupations than other counties. Additional regressions measured remoteness by counting the number of residents within a 200 kilometer radius, or roughly 125 miles of the county center. In these cases, remoteness was not significantly related to the share of high-knowledge occupations. These results indicate that remoteness is a less formidable challenge in supporting rural knowledge based activity.¹⁹

In sum, the empirical results reveal several relationships between the concentration of knowledge occupations and rural areas. Rural communities that provide greater opportunities for personal interaction and the sharing of knowledge had higher concentrations of high-knowledge occupations. These rural communities tend to have larger pools of labor, existing businesses, and a college or university. And natural amenities, which boost the attractiveness of rural locations to knowledge workers, also had higher concentrations of high-knowledge occupations.

III. STRATEGIES TO BUILD A RURAL KNOWLEDGE ECONOMY

Because a variety of factors seem critical to the concentration of knowledge-based activity in rural places, rural leaders are using a variety of strategies to strengthen their economies. Some rural communities are tapping higher education institutions for innovations. Others are leveraging scenic amenities. Many are building 21st century infrastructure. Yet, knowledge economies are strongest where rural communities are building partnerships to overcome their size and remoteness.

Tapping institutions of higher education will be crucial if rural communities are going to strengthen their knowledge economies. Colleges and universities are a primary generator and distributor of knowledge through their research, teaching, and outreach activities. Many of the

economic opportunities emerging in the knowledge economy are being supported by rural institutions that are realigning themselves for the 21st century.

Many colleges and universities have already brought knowledge to rural communities by educating people and transferring technology and knowledge to firms. Some are serving as catalysts for regional partnerships and business networks. Fort Lewis College in Durango, Colorado, was the catalyst to the success of the San Juan Forum in the Four Corners region of the Southwest (Anesi, Eppich, and Taylor). Others serve as a broker of services (Rosenfeld and Sheaff). Oklahoma State University-Okmulgee is helping manufacturers in northeast Oklahoma gain the capacity and certification for Defense Department contracts by helping firms reengineer and reproduce parts wanted by the Defense Department. As a result, Oklahoma vendors have increased their share of contracts at Tinker Air Force Base in Oklahoma City from 3 percent in 1995 to 20 percent in 2002.

Leveraging scenic amenities to attract knowledge workers can be a straightforward strategy. Communities located in scenic areas have an advantage in attracting knowledge workers by increasing quality-of-life amenities, which are becoming increasingly important in worker location choices (Rappaport). In a USDA survey, over 70 percent of rural high-knowledge producer-service firm owners indicated that quality-of-life amenities were a major factor in location choice (Beyers and Lindahl). Natural amenities, especially typography, appear to have a strong relationship with the concentration of knowledge occupations.

Building 21st century infrastructure may be necessary to support knowledge-based activity in the future. Broadband is an example of a new form of infrastructure that may be necessary for a knowledge economy. With broadband, knowledge workers can tap distant knowledge, information, and markets. Because broadband has only recently begun to emerge in rural places, research identifying the contribution of broadband access to economic growth is limited, and most success stories remain as anecdotes.

One illuminating success story is from rural western Maryland. To stimulate economic activity, Garrett County, in cooperation with Garrett County Community College, helped supply high-speed access to the region's businesses and individuals through the Garrett Rural

Information Cooperative.²⁰ Many businesses have chosen to locate in the county because of its telecommunications capabilities. Currently, the co-op is working on an information incubator to house up to 20 start-up firms on the community college campus.

Building partnerships to overcome size and remoteness may be the primary key to sustaining rural knowledge-based activity. Knowledge-based activity is associated with larger economies that provide more knowledge resources. Partnership is one way rural communities can pool knowledge resources. Regional partnerships can expand both the resource pool and market potential to support knowledge-based activity. Therefore, rural communities may want to think regionally. By building partnerships with neighboring places and forming networks, rural communities can capture some of the spillovers that produce growth in a knowledge economy.

In Maddock, North Dakota, the Maddock Economic Development Council formed the Maddock Business and Technology Center (MEDC) in 1999 to create new businesses and high-paying jobs (OECD 2001). MEDC created a high-growth business incubator that provides training classes, business services, and computer access for the community. MEDC has fostered new knowledge-based activity by incubating a satellite imagery company, a multimedia firm, an Internet woman's magazine, and a call center. MEDC also embarked on a telemedicine project to improve the delivery of rural health services.

Informal partnerships can also create success at the firm level. In Dickinson, North Dakota, a \$600 investment in 1995 was turned into a million dollar company that originates and distributes preschool curricula. Originating as a daycare center, Funshine Express has emerged as a knowledge company shipping over 1,500 preschool kits a month.²¹ The company's growth was fostered by participating in manufacturing roundtables and regional economic development programs. These networks provided valuable business advice, financial support, and technology transfers.

IV. CONCLUSIONS

Knowledge is the new fuel powering economic growth in the 21st century. By spurring new ideas and innovations, knowledge boosts productivity and creates new products, new firms, new jobs, and new opportunities. However, few rural places have tapped this economic potential. Many are asking where to start.

A variety of factors are found to be related to knowledge-based growth. Larger rural communities tend to have higher concentrations of high-knowledge occupations because they provide greater opportunities for personal and firm interaction and the sharing of knowledge. These rural communities tend to have larger pools of labor and existing businesses. Communities with a college or university also had high concentrations of knowledge occupations. And, natural amenities appear to be attractive to knowledge workers.

As a result, rural leaders are using a variety of new strategies to strengthen their own knowledge economy. Some are tapping institutions of higher education for innovations to jump-start their knowledge economy. Others are leveraging local amenities to attract knowledge workers. In some rural communities, building new infrastructures may be crucial to a future knowledge economy. But fostering innovative, regional, entrepreneurial partnerships of people, businesses, communities, and institutions could be most essential ingredient to building a rural knowledge economy for the 21st century.

APPENDIX

An empirical model is developed in this appendix to analyze the factors related to the concentration of rural knowledge-based activity. The concentration of knowledge-based activity is measured as the county's share of occupations in knowledge occupations in 2000. Knowledge occupations were defined as managerial, professional, and technical occupations. The empirical model is given below:

$$\begin{aligned} \text{Share of knowledge occupations} = & b_0 + b_1 * \text{Pop Den} + b_2 * \text{Town} \\ & + b_3 * \text{Adjacent} + b_4 * \text{Col. Grad} + b_5 * \text{Knowledge firms} + \\ & b_6 * \text{College} + b_5 * \text{Regional High Knowledge} + b_6 * \text{Geography} \\ & + b_7 * \text{Weather} + b_8 * \text{Interstate} + b_9 * \text{Crime} + b_{10} * \text{Land} \\ & + b_8 * \text{Regional Dummies.} \end{aligned}$$

The empirical model was estimated with cross-sectional data from rural counties. Counties in Alaska and Hawaii were excluded from the analysis. All independent variables were measured with 1990 data unless otherwise specified. The empirical results are presented in the Table A1. The empirical model appears to have a good fit as the adjusted r-square is 0.59. The potential for spatial autocorrelation was addressed following Conley and Rappaport. Empirical results accounting for spatial autocorrelation did not vary from ordinary least squares results that ignored the potential for spatial autocorrelation. Table A2 presents results for a regression analyzing all U.S. counties.

Table A1
EMPIRICAL RESULTS FOR RURAL COUNTIES

VARIABLE	DEFINITION	COEFFICIENT	ST. ERROR
Pop. density	(100 people/sq. mile)	1.14 ***	(0.237)
Town	(County with town >10,000)	0.33 ***	(0.127)
Adjacent	(County adjacent to MSA)	0.139	(0.15)
Col. grad.	(Percent of population with a post-secondary degree)	0.841 ***	(0.043)
Knowledge firms	(Hundreds of establishments in Beck's high-knowledge industries)	0.464 ***	(0.092)
College	(County with dorm population)	0.916 ***	(0.152)
Region high-knowledge	(Share of high-knowledge occupations within 200 km (roughly 125 miles) of county center excluding originating county)	0.302 ***	(0.083)
Geography	(Sum of county center excluding originating county)	0.307 ***	(0.061)
Weather	(Sum of USDA z-score index of topography and water surface area)	-0.047	(0.065)
	(Sum of USDA z-score index of Jan and July mean temperature, January hours of sun, and July humidity)		
Interstate	(County with an interstate in 1992)	-0.016	(0.136)
Crime	(Crimes per square mile)	-0.022	(0.013)
Land	(County land area square miles)	0.17 **	(0.08)
Midwest	(Dummy variables for Midwest states)	-0.244	(0.382)
South	(Dummy variables for South states)	0.349	(0.393)
Southwest	(Dummy variable for Southwest states)	0.763 *	(0.425)
West	(Dummy variable for Western states)	-0.296	(0.461)
Intercept		5.955 **	(2.684)
Adjusted R-sq		0.5903	
Observations		2246	

*** Significant at the 0.01 level **Significant at the 0.05 level. *Significant at the 0.10 level.

Southern states include Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. Midwest states include Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. Southwest states include Arizona, New Mexico, Oklahoma, and Texas. Western states include California, Colorado, Idaho, Montana, Nevada, Oregon, Utah, Washington, and Wyoming.

Table A2
EMPIRICAL RESULTS FOR ALL U.S. COUNTIES

VARIABLE	DEFINITION	COEFFICIENT	ST. ERROR
Pop. density	(100 people/sq. mile)	0.004	(0.006)
Town	(County with town >10,000)	0.385 ***	(0.132)
Metro	(County is located in an MSA)	2.916 ***	(0.218)
Col. grad.	(Percent of population with a post-secondary degree)	1.13 ***	(0.034)
Knowledge firms	(Hundreds of establishments in Beck's high-knowledge industries)	0.004	(0.003)
College	(County with dorm population)	0.663 ***	(0.147)
Region high knowledge	(Share of high-knowledge occupation within 200 km (roughly 125 miles) of county center excluding originating county)	0.181 **	(0.082)
Geography	(Sum of USDA z-score index for typography and water surface area)	0.265 ***	(0.056)
Weather	(Sum of USDA z-score index of Jan and July mean temperature, January hours of sun, and July humidity)	-0.197 ***	(0.066)
Interstate	(County with an interstate in 1992)	0.378 ***	(0.121)
Crime	(Crimes per square mile)	0.007	(0.014)
Land	(County land area square miles)	0.092	(0.065)
Midwest	(Dummy variables for Midwest states)	-0.702 ***	(0.282)
South	(Dummy variables for South states)	0.507	(0.323)
Southwest	(Dummy variable for Southwest states)	0.631 *	(0.353)
West	(Dummy variable for Western states)	-0.811 **	(0.39)
Intercept		8.552 ***	(2.692)
Observations		3053	
Adjusted R-sq		0.7930	

*** Significant at the 0.01 level. ** Significant at the 0.05 level. * Significant at the 0.10 level.

Southern states include Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. Midwest states include Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. Southwest states include Arizona, New Mexico, Oklahoma, and Texas. Western states include California, Colorado, Idaho, Montana, Nevada, Oregon, Utah, Washington, and Wyoming.

ENDNOTES

¹There are many definitions of knowledge. For example, disembodied knowledge includes knowledge that emerges in product and processes represented by patents. Embodied knowledge includes knowledge contained in physical capital—that is, the latest machine tool or computer servers, or human capital (the ability to analyze information, write a document, or build a cabinet). This article defines knowledge as the type embodied in human capital.

²Economists have recognized the direct and indirect effects of knowledge on economic growth in New Growth Theory, which recognizes that the stock of knowledge and its spillovers affect growth (Romer). See Stiroh for a comparison of neoclassical and new growth theories in explaining productivity and output growth.

³The Bureau of Labor Statistics defines knowledge as “the nature and extent of information or facts which the workers must understand to do acceptable work (for example, steps, procedures, practices, rules, policies, theories, principles, and concepts) and the nature and extent of the skills needed to apply those knowledges.”

⁴This method assumes that knowledge impacts economic performance at the industry level by increasing industry productivity and growth (OECD 1996).

⁵Occupational categories were slightly revised for the 2000 Census. Knowledge occupations for 1980 and 1990 were defined as executive, administrative, and managerial occupations, professional specialty occupations, and technical occupations. Knowledge occupations for 2000 were defined as management occupations, business and financial occupations, and professional and related occupations.

⁶Beck’s classification of high-, moderate-, and low-knowledge industries was used as the industry measure of knowledge-based activity. In analyzing the role of knowledge in the Canadian economy in the 1980s and early 1990s, Lee and Has classified industries into high, medium, and low categories using measures of research and development and human capital. Research and development measures were included to measure the ability of firms to produce knowledge in addition to use knowledge. Beck’s classification is used because it was based on U.S. industry data. But similar results were found using Lee and Has’s classification of high-, medium-, and low-knowledge industries.

⁷The adoption of the North American Industry Classification System (NAICS) by the County Business Patterns data in 1998 limits the comparison of industry growth from the years prior to 1998 and the years after 1998. Analysis of 2002 data using an incomplete bridge between the NAICS and the Standard Industrial Classification System (SICS) indicates that high-knowledge industries account for a larger share of U.S. establishments and employment in 2002 than in previous years.

⁸Occupation data are based on place of residence.

⁹Rural counties are defined as all counties defined as nonmetro in 1990 according to the Office of Management and Budget classification scheme. In this classification, some small metro areas that may be commonly perceived as rural are defined as metro.

¹⁰County-level analysis is undertaken due to the availability of data and the distinction of metro and nonmetro areas on a county basis. The article discusses regression analysis of the concentration of knowledge-based occupations in rural (nonmetro) areas only. Empirical results from analysis incorporating all U.S. counties are presented in Table A2 of the appendix.

¹¹The cross-sectional regression only identifies potentially simultaneous relationships and does not necessarily identify causality. To mitigate the potential problem of endogeneity, data on existing establishments and infrastructure were obtained for years as close to 1990 as possible.

¹²Educational attainment had a stronger relationship with the concentration of knowledge occupations in analysis using all U.S. counties. In this regression, a 1 percent increase in educational attainment was related to a 1.13 percent increase in the concentration of knowledge occupations (Table A2).

¹³The significant relationship between college and the concentration of knowledge occupations could be driven by the fact that colleges employ a large number of people in knowledge occupations. Additional regressions that did not include educators in the occupation data still found the college variable to be significant.

¹⁴Analysis using all U.S. counties found that counties with a college had a 0.66 percent higher concentration of knowledge occupations.

¹⁵Other local amenities, such as low crime rates, are related to the growth of high-tech firms (Goetz and Rupasingha). However, the empirical results do not find crime rates to be related to the concentration of knowledge occupations.

¹⁶Regression results analyzing all counties found a significant relationship between interstates and the concentration of knowledge occupations (Table A2).

¹⁷Size provides benefits arising from agglomeration. Agglomeration forces are commonly grouped into two broad categories: localization and urbanization (Henderson, Kuncoro, and Turner). Localization benefits arise from a concentration of similar firms and industries. Urbanization benefits arise from a concentration of people and being near urban economies.

¹⁸Regional concentrations of knowledge activity appears to be more important for rural counties. Analysis using all U.S. counties found a smaller coefficient with the Region High Knowledge variable, 0.18 for all U.S. counties (Table A2) compared to 0.30 for rural counties (Table A1).

¹⁹Empirical analysis that included all U.S. counties found that counties in a metro area had higher concentrations of knowledge occupations than rural (nonmetro) counties. However, the variables measuring the urbanization and localization benefits of size (*Pop. density and Knowledge-firms*) were insignificant. Thus, the metro dummy variable may not be a measure of remoteness, but a measure of size.

²⁰The Garrett County Community College and additional community college case studies are published in “Cultivating Successful Rural Economies: Benchmark Practices at Community and Technical Colleges,” produced by Regional Technology Strategies, Inc. and available at www.rtsinc.org.

²¹Funshine Express was highlighted as the Entrepreneur of the Month by the Center for Rural Entrepreneurship. A detailed case study is available at www.ruraleship.org.

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