AN OVERVIEW OF THE KNOWLEDGE ECONOMY, WITH A FOCUS ON ARIZONA

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P3 | PRODUCTIVITY AND PROSPERITY PROJECT

ASU W. P. CAREY SCHOOL of BUSINESS
ARIZONA STATE UNIVERSITY

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SUMMARY

"Knowledge economy" is a term used in advanced economies to describe trends in which the creation of knowledge and its use as an input in the production process are increasingly important factors in the pursuit of prosperity and competitiveness. Knowledge is now recognized as the driver of productivity gains and economic growth, leading to a new focus on the role of information, technology and learning in economic performance. The broadest definition of the knowledge economy is one in which the production, distribution, and use of knowledge plays a key role throughout the economy.

Anything that increases the quantity or quality of the factors of production available to the economy or improves the technology available to the economy contributes to economic growth. Economic growth leads to increases in real income and rising living standards. Knowledge accumulation also contributes directly to enhancing living standards by providing new or improved products and services. The creation of knowledge and the application of the accumulated stock of knowledge have had an increasingly important contribution to the growth process. On average, nearly 70 percent of recent economic growth in the United States and other advanced economies was the result of technological change.

Knowledge has three characteristics that have very important implications for the knowledge economy: it can be used over and over without being consumed by that use, it can be used by many individuals at the same time, and it can be used in many different locations simultaneously. The economics of knowledge are very different than for ordinary goods and services. Knowledge can produce economic value not only to its creator, but through diffusion of the knowledge there is also the potential for it to produce economic value for many other users. Thus, the overall value of knowledge to society increases to the extent that it is shared and used by others.

Because the value to society of knowledge is often much greater than the private economic value to its creator or owner leads to another difference between knowledge and ordinary goods and services: a wide divergence can exist between the private return on investment to create knowledge and the return on investment from society's point of view. Under these conditions, the private sector allocates too few resources and public sector intervention is needed to fully realize the societal benefits.

The information revolution and the transition to a knowledge economy have been accompanied by increased globalization. Explicit knowledge — that which can be codified and easily shared — flows more quickly and widely than ever before. Paradoxically, the key role of tacit knowledge — that which cannot be codified, requiring face-to-face contact — in the innovation process leads to geographic concentration of the processes of knowledge creation and innovation. That in turn leads to clustering of knowledge-based firms and knowledge workers, usually in metropolitan areas.

While globalization has provided opportunities for U.S. firms, the emergence of the global knowledge economy presents real challenges to the economic leadership that the United States has enjoyed since World War II. The processes that the United States has relied upon to produce economic growth and prosperity — the creation of new knowledge and investment in human

capital and advanced technology — will surely continue, but similar processes are occurring around the globe.

Colleges and universities perform two fundamental functions in the knowledge economy: producing human capital and creating new knowledge. While many of the contributions colleges and universities make to the knowledge economy are distributed widely, their educational and research activities also benefit the local region in which they are located. Universities with the greatest local economic impacts are generally those with the highest quality research programs. Knowledge-based firms want to locate near universities to tap into faculty who are on the leading edge of scientific breakthroughs. University scientists with a national reputation also are more likely to be able to attract venture capital, management, and the technical workers necessary to start new companies.

Measurements of the knowledge economy can be made by industry or by occupation. The latter measures the knowledge economy directly in terms of the number of “knowledge workers.” This approach has the advantage over the industry-based approach in recognizing that knowledge workers may be employed across all sectors of the economy and that not all workers in knowledge-intensive industries are knowledge workers. Based on occupation, knowledge workers accounted for nearly 31 percent of all workers in the United States in 2010. Knowledge-based industries in the United States employed 34 percent of the total in 2009.

Various studies evaluating the knowledge economy give the United States very good but not top ratings, with the United States declining over time relative to the top-ranked economies. Looking at the individual dimensions of the knowledge economy, the United States has its highest rankings for factors relating to research and development and innovation and its lowest rankings for education and technological readiness. Evaluations of the knowledge economy by U.S. state indicate that Arizona is in the second tier, ranking 15th overall in one study and 20th overall on another. Arizona’s primary weakness is in human capital.

Though economic development agencies in Arizona have pursued knowledge-intensive industries, these efforts have met with limited success. The concentration of high-technology activities in Arizona has continued to decline, so that Arizona no longer has a high-technology presence much different than the national average. In addition, Arizona continues to have a narrow base of high-technology activities. Only two activities with substantial employment — manufacturing of aerospace products and manufacturing of semiconductor and other electronic components — have a much greater relative presence in Arizona than the national average. As a result, per capita income levels in Arizona have fallen to far below the national average and also below the levels in most of its “competitor” states.

The creation, distribution, and application of knowledge — the bases of the knowledge economy — have been the most important factors driving the dramatic rise in living standards in the United States. Barring unforeseen game-changing phenomena, the knowledge economy will continue to be the key driver of economic growth and prosperity in the future. Fundamental changes in the Arizona economy appear to be needed if the state is to fully participate in the global knowledge economy of the 21st century.

INTRODUCTION

The knowledge economy is a term used in advanced economies to describe trends in which the creation of knowledge and its use as an input in the production process are increasingly important factors in the pursuit of prosperity and competitiveness. Knowledge is now recognized as the driver of productivity gains and economic growth, leading to a new focus on the role of information, technology and learning in economic performance.

The purpose of this paper is to provide an overview of the knowledge economy and discuss Arizona's place in the national and global knowledge economies. The content of the report is organized into the following seven sections:

- Definition of the knowledge economy.
- The importance of knowledge creation for economic growth and prosperity.
- Characteristics of knowledge and other factors that contribute to the crucial role that the knowledge economy plays in today's world.
- The key role of colleges and universities in the knowledge economy.
- Benchmarking America's performance in the global knowledge economy.
- How Arizona ranks among the U.S. states.
- Ways in which the state can improve its competitive position in the knowledge economy.

DEFINING THE KNOWLEDGE ECONOMY

Alternative Definitions

Although the term "knowledge economy" is widely used, there does not really seem to be a single agreed-upon definition of the term. Instead, at least three alternative concepts of the knowledge economy have been forwarded:

1. **The part of the economy involved in the production and distribution of knowledge**. This concept of the knowledge economy comes from Fritz Machlup, whose 1962 study analyzed the production and distribution of knowledge in the United States. While his work has generated wide and continued interest in the economics of knowledge and information, current references to the knowledge economy are much more likely to involve a broader definition. The more popular uses of the term might actually be better described by the expression "knowledge-based economy" to distinguish from the narrower definition.

2. **The part of the economy composed of knowledge-intensive industries**. This concept divides the economy into two sectors: (a) the knowledge-intensive sector made up of those industries whose firms employ advanced technologies and have highly educated and skilled workforces, and (b) the sector that is not knowledge intensive, composed of industries with less educated/skilled workforces that use "traditional" production processes.

3. **The characterization of an entire economy in which the production, distribution, and use of knowledge plays a key role throughout the economy**. Knowledge-based growth involves not just the creation of new sectors but the internal transformation of sectors that already exist. Focusing on only the high-technology sector or so-called knowledge-intensive industries because they are perceived to be where new ideas are discovered and new technology is developed

ignores reality. Just because modern economies are more knowledge intensive, this does not necessarily mean that only some sectors are participants in the knowledge economy.

It might well be argued that the growth trajectories of advanced economies depend as much on so-called "low-tech" sectors such as the production of food, wood products, and vehicles as on radically new sectors like information technology (IT) or biotech. Many new industries have grown rapidly, but from a very low base. They still provide only a low share of total economic output (Smith 2000).

Related Concepts

While dealing with definitions, it may be useful to consider three other concepts that are related but not equivalent to the knowledge economy: the "new economy," "high technology," and the "creative class."

The "new economy" was a concept popularized in the 1990s to describe the transition from a traditional industrial economy to one based on technology. In its heyday, the new economy was said to be characterized by rapid productivity growth, rapid technological change (particularly associated with computers and IT), and the absence of business cycles and inflation. The dot-com crash and the 2001 recession largely ended such a rosy view of the new economy, but the term continues to exist and is often used to denote a concept similar to the knowledge economy. In its current formulation, the new economy is "knowledge-based, globalized, entrepreneurial, IT-driven, and innovation-based" (Atkinson and Andes 2010). Thus, both concepts stress the importance of knowledge and technology, with the new economy concept also explicitly emphasizing entrepreneurship and globalization.

In both policy analysis and popular literature, it is common to use the terms "high-technology" and "knowledge intensive" or "knowledge based" in a somewhat loose way, as though they are interchangeable terms. For example, the complete title of a recent Milken Institute report is *North America's High-Tech Economy: The Geography of Knowledge-Based Industries* (DeVol, et. al. 2009). However, the terms "knowledge intensive" and "knowledge economy" are much broader concepts than the high-technology sector as conventionally defined. The definition of "high technology" used by the U.S. Bureau of Labor Statistics is based solely on the proportion of scientists, engineers, and technicians in the workforce (Hecker 2005). The Organization for Economic Cooperation and Development (OECD) considers only manufacturing sectors in its definition of high technology and is based on research and development (R&D) expenditures (OECD 2011). (The OECD is an international organization of 34 countries founded in 1961 to stimulate economic progress and world trade.)

The concept of the "creative class" popularized by Richard Florida (2002) also has some similarities with the knowledge economy. The "creative class" or the "creative economy" concepts focus exclusively on the human capital segment of the knowledge economy. They identify a creative, highly educated and/or skilled workforce as the key factor for economic development in postindustrial economies. In practice, the Florida definition of creative class workers is very similar to what are termed "knowledge workers" in knowledge economy discussions (managerial, professional, and related occupations), but Florida emphasizes the importance of what are termed "the supercreative core" who "fully engage in the creative process” as the real driver of new ideas, innovation, and economic development. The contention that the creative class is the key to economic growth has been subject to considerable criticism as being based on casual observation and not supported by empirical evidence (see, for example, Malanga 2004).

THE IMPORTANCE OF KNOWLEDGE CREATION FOR ECONOMIC GROWTH

Anything that increases the quantity or quality of the factors of production available to the economy or improves the technology available to the economy contributes to economic growth. Economic growth leads to increases in real income and rising living standards. Knowledge accumulation also contributes directly to enhancing living standards by providing new or improved products and services. The creation of knowledge and the application of the accumulated stock of knowledge have had an increasingly important contribution to the growth process. (The discussion in this section is based on Blakemore and Herrendorf (2009).)

Economists have developed increasingly sophisticated models of economic growth that provide theoretical support for the importance of knowledge accumulation, and empirical analyses of the sources of economic growth in the United States and other countries provide statistical evidence of the key role of knowledge as the most important source of growth in advanced economies.

The traditional model of economic growth is based on the well-known concept of the production function in which the two primary economic inputs — labor and capital — are combined in a production process with known techniques. In the context of a national or regional economy, the analysis is framed in terms of a so-called “aggregate” production function in which an economy’s productive capacity is a function of three variables: its labor force, its stock of capital equipment, and its level of technology. Based on such an economic model, three sources of growth are evident: (1) growth of the labor force; (2) growth of the stock of capital; (3) improvements in technology.

In this traditional model of economic growth, two of these three factors — labor and capital — are subject to what is popularly known as “diminishing returns.” This concept refers to the fact that, with fixed technology, incremental additions of more workers or more capital will produce smaller and smaller additional amounts of output, and at the limit further additional inputs will produce no additional output. Thus, the traditional model of economic growth implies that without technological change, the economy would tend to grow at a slower and slower rate and ultimately reach a long-run equilibrium level of output with no further growth possible. Technological progress, however, is not subject to diminishing returns in the same way as the other two factors. Thus, the traditional model of economic growth demonstrates that technological progress is the key to sustaining economic growth over time.

Another aspect of knowledge accumulation is its impact on the stock of human capital — the knowledge that workers acquire through education and training. Human capital contributes to economic growth in several ways. Education and training improve labor productivity even with fixed technology. However, more skilled and highly educated workers are usually required to take advantage of advances in technology. Human capital is also a key ingredient for the creation and diffusion of new technology.

Although knowledge is recognized as a key factor in economic growth in traditional growth models, the impact of knowledge appears only as an unexplained residual not explained by increases in the capital stock or other measurable inputs. Economists have developed more sophisticated models that incorporate knowledge and technology more explicitly. This area of research popularly known as “new growth theory” has developed models in which knowledge is the main engine of economic growth, often explicitly including both the accumulation of knowledge via technical progress and the role of human capital (see, for example, Romer 1990; Chen and Kee 2005).

In addition to theoretical analyses of economic growth, a large and growing body of literature has empirically investigated the determinants of economic growth and has generally found evidence of the growing importance of knowledge-related factors. For example, Jones (2002) estimated that the production of new knowledge (measured by research and development activity) and increased educational attainment accounted for more than 80 percent of U.S. economic growth over the 1950-to-1993 period. In another analysis of U. S. economic growth in the last half of the 20th century, Jorgenson (2005) found that for the 1948-to-2002 period as a whole about 60 percent of economic growth stemmed from increases in the quantities of capital and labor and 40 percent from increases in the qualities of the factors of production and improvements in technology. In the most recent part of the period (1995-to-2002), however, he found that these percentages were essentially reversed, with a little less than 30 percent explained by increases in quantities of the factors of production and 70 percent due to improvements in factor quality and technology. Similarly, in a cross-country study of 22 advanced economies (including the United States), Aghion and Howitt (2007) estimated that on average nearly 70 percent of recent economic growth was the result of technological change.

CHARACTERISTICS OF THE KNOWLEDGE ECONOMY

Economics of Knowledge

Knowledge has three characteristics that have very important implications for the knowledge economy: it can be used over and over without being consumed by that use, it can be used by many individuals at the same time, and it can be used in many different locations simultaneously.

The economics of knowledge are very different than for ordinary goods and services. Knowledge can produce economic value not only to its creator, but through diffusion of the knowledge there is also the potential for it to produce economic value for many other users. Thus, the overall value of knowledge to society increases when it is shared and used by others.

To the extent that diffusion of knowledge can be restricted, it is often in the interest of the creator or original owner of knowledge to restrict its use for private gain. The creator or original owner also may gain private economic value from selling or licensing the knowledge for use by others. Given its unique characteristics, the potential private gains can be large, since it could be sold or licensed to a large number of other users. Thus, a conflict exists between private property rights and the social value of the diffusion of knowledge.

Because the value to society of knowledge is often much greater than the private economic value to its creator or owner leads to another difference between knowledge and ordinary goods and services: a wide divergence can exist between the private return on investment to create knowledge and the return on investment from society's point of view. The more that the knowledge is distributed and put to more and more uses, the greater is the social return on investment in knowledge.

The Information Revolution

The information revolution brought about by advances in computing and information/communications technologies allows the storage, management, and transmission of information at a very low cost. The distribution of these technologies has been pervasive, to all economic sectors and around the world. As a result, the world's stock of knowledge is much more accessible than in the past, making it much easier to undertake knowledge-based activities anywhere in the world. These developments stimulate increases in knowledge-based economic activity and acceleration in the creation of new knowledge, both of which have positive impacts on economic growth.

Globalization

A rapid globalization of economic activity has occurred. Reductions in tariffs and nontariff barriers and deregulation of markets in many countries have spurred international trade flows of goods and services. The deregulation of financial markets and the reduction of barriers to foreign direct investment (FDI) and other international capital flows have led to the integration of world financial and capital markets and increasing flows of FDI and other capital to developing countries. One result of these trends has been the development of a global knowledge economy. Firms in the United States and other developed nations have expanded their business operations globally, and indigenous knowledge-intensive sectors have grown rapidly in many countries around the world.

This globalization has impacted the U.S. economy in many ways. U.S. firms have become increasingly subject to foreign competition, but at the same time they have looked more toward global markets and have taken advantage of lower-cost foreign suppliers. To take advantage of opportunities provided by globalization, firms have become multinational, establishing worldwide supply, production, and distribution networks. Many workers at firms that have successfully adapted to globalization have benefited, but large numbers of U.S. jobs have disappeared due to foreign competition or to offshoring by domestic firms. In effect, globalization means a substantial portion of the U.S. workforce is directly or indirectly in competition with lower-wage workers around the world.

Tacit and Explicit Knowledge

Much of the stock of knowledge is explicit knowledge — information in printed or electronic form that can be easily transferred and shared with others. The process of transforming knowledge into explicit knowledge is often referred to as "codification," and explicit knowledge is also known as codified knowledge. On the other hand, some types of knowledge involve learning and skill that cannot be codified or easily shared. This is often referred to as tacit knowledge. The tacit aspects of knowledge are those that can only be transmitted via training or gained through personal experience. For example, printed plans for a bicycle are a form of codified knowledge, but the skill or knowledge of how to ride a bicycle is tacit knowledge.

The information/communication revolution has led to a global knowledge economy, where explicit knowledge can be easily transferred and put to use almost anywhere around the world. But at the same time, tacit knowledge is very local in character and is difficult to transfer without personal interaction. This is especially true of recently created knowledge. In many cases, newly created knowledge is tacit and difficult to codify. The knowledge is embodied in the human capital of the discoverer(s) and only can be transferred to others through personal working relationships with the individual(s).

Social networks play an important role in the diffusion of information and knowledge since they provide the formal connections and informal linkages through which information and ideas flow among individuals. Concentrating people engaged in related activities in a particular location thus creates an environment that facilitates the rapid and effective diffusion of ideas. Much of Silicon Valley's success, for example, has been attributed to its informal networks of friendship and collaboration among scientists, engineers, and entrepreneurs in the area (Charney et. al. 2007).

The characteristics of tacit knowledge that tend to concentrate knowledge creation and innovative activities, together with forces economists term agglomeration economies, often lead to the clustering of knowledge-based firms and knowledge workers near the location where the new idea was originally developed. Again, the prime example of this phenomenon is Silicon Valley.

Agglomeration economies are a powerful force that helps explain the advantages of the "clustering effect" of many activities ranging from retailing to transport terminals. Agglomeration economies consist of three major categories (Rodrique et. al. 2009):

- **Urbanization economies**: benefits derived from the agglomeration of population, namely common infrastructures (e.g. utilities or public transit) and the availability and diversity of labor and market size.
- **Industrialization economies**: benefits derived from the agglomeration of industrial activities, such as to their respective suppliers or customers.
- **Localization economies**: benefits derived from the agglomeration of a set of activities near a specific facility, such as a transport terminal (logistics parks), a seat of government (lobbying, consulting, law) or a large university (technology parks).

More generally, the combination of agglomeration economies and tacit knowledge leads to concentrations of knowledge-intensive industries and of knowledge workers in metropolitan areas.

Embodied and Disembodied Technology

Technology is the term for the knowledge associated with the development, design, production, and application of products, processes, and services. The term also is often used to refer to the products, processes, and services themselves. Technology is usefully categorized in two forms. Disembodied technology is codified knowledge, such as patents, technical reports, manuals, databases, etc. Embodied technology is incorporated in new or improved products, processes, and services. Embodied technology is a primary way in which new knowledge is distributed and employed in the knowledge economy. Investment in new capital equipment and/or use of new services that embody technological advances is a key mechanism for increasing the knowledge intensity of existing businesses or other activities.

Implications

The unique economic characteristics of knowledge and the information revolution have been key factors underlying acceleration in the rate of knowledge accumulation, which in turn has stimulated increases in the knowledge intensity of the U.S. economy. The production of new knowledge (measured by research and development activity) and increased educational attainment accounted for more than 80 percent of U.S. economic growth in the post-World War II era. Thus it is not exaggerating to say that the high standard of living in the United States is in large part the result of the productivity of well-trained people and the growing stream of scientific and technical innovations that they have developed.

The information revolution and the transition to a knowledge economy have been accompanied by increased globalization. Explicit knowledge flows more quickly and widely than ever before. Paradoxically, the key role of tacit knowledge in the innovation process leads to geographic concentration of the processes of knowledge creation and innovation. That in turn leads to clustering of knowledge-based firms and knowledge workers, usually in metropolitan areas.

While globalization has provided opportunities for U.S. firms, the emergence of the global knowledge economy presents real challenges to the economic leadership that the United States has enjoyed since World War II. The processes that the United States has relied upon to produce economic growth and prosperity — the creation of new knowledge and investment in human capital and advanced technology — will surely continue, but similar processes are occurring around the globe. Concerns have been increasing about how the United States can successfully compete and prosper in the global community of the 21st century, and the business community, government officials, and other policymakers are working to develop policies aimed at strengthening and stimulating the U.S. knowledge economy (see for example Task Force on the Future of American Innovation 2005, National Academy of Sciences 2007, and U. S. Office of Management and Budget 2011).

KEY ROLE OF COLLEGES AND UNIVERSITIES IN THE KNOWLEDGE ECONOMY

Colleges and universities perform two fundamental functions in the knowledge economy: producing human capital and creating new knowledge.

Producing Human Capital

The U.S. higher education system (including two-year, four-year, and graduate institutions) produces the highly educated workers needed in the knowledge economy. They also train the educators that are a key ingredient for elementary and secondary education.

University graduate programs have multiple roles. They produce the scientists, engineers, and other highly skilled individuals that are the research workers in industry, research labs, and universities. Graduate programs also turn out individuals with doctorate degrees (Ph.D.s) that in turn join the faculties of other colleges and universities and educate succeeding generations of undergraduate and graduate students.

Knowledge Creation

Colleges and universities, particularly research universities, create knowledge. Hoffman (2008) identified six benefits from university research:

- Expansion of the stock of knowledge.
- Training of future researchers.
- Creation of new instrumentation and methodologies.
- Formation of networks and stimulation of social interaction.
- Increases in the capacity for scientific and technological problem solving.
- Creation of new firms.

Hill (2006a) discusses the role of universities in what is sometimes referred to as the "national innovation system" — the system of government agencies, business firms, universities, and other institutions involved in R&D activities. In the U.S. national innovation system, almost all of the development activity is undertaken by private industry, while the majority of research is done at universities. Compared to other countries, a relatively large percentage of U.S. basic research is performed at universities by faculty who are also actively involved in educating students, especially graduate students.

Regional Economic Development

While many of the contributions of colleges and universities to the knowledge economy are distributed widely, their educational and research activities also benefit the local region in which they are located. The most spectacular examples of local economic development stimulated by university research are the electronics clusters in Silicon Valley (with ties to Stanford University) and Route 128 near Boston (with ties to the Massachusetts Institute of Technology). But there are also many other cases of local industries developed from the ideas of university scientists. More generally, studies based on data for a large sample of research universities show that university research programs have significant local economic impacts, though usually modest in size. (This discussion is based upon Hill (2006b).)

Universities with the greatest local economic impacts are generally those with the highest quality research programs. Knowledge-based firms want to locate near universities to tap into faculty who are on the leading edge of scientific breakthroughs. University scientists with a national reputation also are more likely to be able to attract venture capital, management, and the technical workers necessary to start new companies.

Research universities also generate local economic impacts through their graduate programs. Availability of highly trained knowledge workers is important to managers of industrial laboratories and other technology-based firms, and they may choose to site a lab in an area if local universities can provide a steady supply of highly qualified science and engineering graduates. See Crow (2005) for a discussion of a broader view of the role of a university in the knowledge economy in the 21st century.

MEASURING THE KNOWLEDGE ECONOMY

No "official" definition of the knowledge economy is used by U. S. statistical agencies. Definitions have been developed by analysts and organizations for their own purposes, but they are not consistent and frequently data based on such ad hoc definitions are not reported on an ongoing basis. Two primary approaches to defining the knowledge economy have been used: by industry (an output-based measure) or by occupation (an input-based measure).

An industry-based approach defines the knowledge economy as either (a) those industries that are involved in the production or creation of knowledge or more often (b) in terms of those industries determined to be “knowledge intensive” or “knowledge based.” Various methods have been used to define the degree of knowledge intensity, often in terms of the educational attainment of its workers or by first defining “high-knowledge” occupations (see discussion below). The knowledge intensity of an industry is then defined in terms of the proportion of its labor force in those “high-knowledge” occupations.

Based on this approach, the OECD has defined the knowledge economy to include high- and medium-technology manufacturing, high value-added service industries (finance and insurance, telecommunications, business services), and the education and health sectors (Brinkley 2006). Using this definition, the OECD estimated that the U.S. knowledge economy accounted for about 43 percent of gross value added in 2002 (OECD 2005). Gross value added is a measure in economics of the value of goods and services produced in an area, industry or sector of an economy. Gross domestic product (GDP) is calculated as gross value added plus taxes on products less subsidies on products.

The second approach is to measure the knowledge economy directly in terms of the number of “knowledge workers.” This approach has the advantage over the industry-based approach in recognizing that knowledge workers may be employed across all sectors of the economy and that not all workers in knowledge-intensive industries are knowledge workers. Conceptually, a knowledge worker might be defined as someone who works at the tasks of developing or using knowledge, but in practice it is usually defined in terms of “high-knowledge” occupations. Unfortunately, there is no single accepted definition of “high-knowledge” occupations. While some organizations have engaged in detailed analyses based on multiple criteria to categorize an occupation’s skill and complexity level (notably the U. S. Bureau of Labor Statistics and Statistics Canada), most often knowledge workers are defined as workers in the managerial, professional, and technical occupations.

The U.S. Bureau of Labor Statistics annually reports occupational employment and wages based on a survey of employers. The hundreds of occupations are categorized into 22 occupational groups in the Standard Occupational Classification (SOC). Defining knowledge workers by occupational group (see Table 1), there were about 39 million in the United States in 2010, nearly 31 percent of all workers. Education, training, and library occupations make up the largest share of U. S. knowledge workers (about 22 percent), followed by the health care practitioner and technical occupations (19 percent). The other two sizable occupational groups are management and business and financial operations.

To produce a comparable estimate using the industry-based approach for this paper, a list of industries to be considered as part of the knowledge economy has been developed. This list is a blend of the OECD definition and definitions developed by the Massachusetts Department of Workforce Development (MDWD 2007). For their own use, the MDWD identified NAICS 4-digit industry groups that make up both a narrowly defined set of “knowledge-creation

TABLE 1
KNOWLEDGE ECONOMY EMPLOYMENT BY OCCUPATIONAL GROUP
UNITED STATES, 2010

	Number in Millions	Share of All Knowledge Workers
TOTAL OF ALL OCCUPATIONS	127.1	
KNOWLEDGE WORKER TOTAL	39.2	100.0%
Management	6.0	15.4
Business and Financial Operations	6.1	15.6
Computer and Mathematical	3.3	8.4
Architecture and Engineering	2.3	5.9
Life, Physical and Social Sciences	1.1	2.8
Community and Social Services	1.9	4.8
Legal	1.0	2.6
Education, Training, and Library	8.5	21.7
Arts, Design, Entertainment, Sports, and Media	1.7	4.3
Healthcare Practitioner and Technical	7.3	18.6

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

industries" and a broader set of knowledge-based or knowledge-intensive industries. This broader set includes selected high-technology industries, information technology industries, financial service industries, and health care industries. Appendix Table A-1 lists the NAICS industry groups (including some government categories not defined in this manner in NAICS) used in this definition of the knowledge economy.

Based on this definition, the knowledge-based industries in the U. S. employed nearly 46 million, 34 percent of the total in 2009 (the latest year of data). Looking at the industry groups in the knowledge-intensive sector in more detail (see Table 2), the knowledge-creation industries — almost all related to education — make up nearly one-third of the total, the single largest component. High-technology industry groups account for about 13 percent of the total knowledge economy in terms of employment, primarily in the high-tech services component. The information technology sector employs about 3 percent of workers in the knowledge economy. This leaves more than half of all jobs in the knowledge economy in the three categories of the "other knowledge-based industries" component: professional services, financial services, and especially health care.

The numbers produced by both definitions are useful for different purposes, but as measures of the size or importance of the knowledge economy they give somewhat different results. The industry-based approach produces a larger estimate of the size of the knowledge economy than counting knowledge workers. Since the two measures are based on different methodologies and the data used to produce the two measures come from different sources, it is not surprising that they do not match. Although many factors undoubtedly contribute to the gap, the important conceptual reason for the difference is the fact that many knowledge workers are employed outside the set of industries included in the industry-based definition while not all of those employed in knowledge industries are in fact knowledge workers. Regardless of the approach, the knowledge economy employs approximately one-third of the U.S. workforce.

TABLE 2
KNOWLEDGE ECONOMY EMPLOYMENT BY INDUSTRY
UNITED STATES, 2009

	Number in Millions	**Share of Total Knowledge-Based**
TOTAL OF ALL SECTORS	134.3	
TOTAL KNOWLEDGE-BASED	45.6	100.0%
High-Technology Manufacturing*	1.6	3.5
High-Technology Services**	4.3	9.4
Knowledge Creation***	14.8	32.5
Information Technology***	1.5	3.3
Other Knowledge-Based***:		
Professional Services	6.6	14.5
Financial Services	6.2	13.6
Health Care	10.6	23.2

Notes (see Appendix Table A-1):
* Six manufacturing industry groups included in the BLS definition of level I high-technology industries
** Ten services industry groups included in the BLS definition of level I high-technology industries
*** Industry groups included in the DMWD definition, excluding any overlap with the BLS high-technology groups

Source: U.S. Department of Commerce, Census Bureau: *2009 County Business Patterns* and *2009 Government Employment and Payroll*.

BENCHMARKING THE U.S. KNOWLEDGE ECONOMY

The U. S. statistical agencies do not compile data relating to the knowledge economy per se, but they do provide a wide variety of information relating to various aspects of knowledge-related activity:

- Education statistics, such as the proportion of college graduates or those with advanced degrees, number of science and engineering Ph.D.s employed, or funding levels for graduate study in science and engineering.
- Information relating to R&D and innovation, such as various measures of R&D expenditures, statistics on research centers or personnel, or data on venture capital or initial public offerings.
- Indirect measures of knowledge creation, such as data on scientific publications or patents.
- Economic data, such as employment, production, investment, or international trade relating to specific technology sectors, such as information technology.

Growth of the U.S. Knowledge Economy

Analysis of such data series demonstrates that U.S. investments in both technology and human capital have grown significantly in the last 50 years and further suggest that the pace of knowledge accumulation accelerated at the end of the 20th century.

For example, data relating to research and development activity show that R&D expenditures (measured in constant dollars) have grown fivefold since 1960, and the average annual growth rate for R&D expenditures increased from less than 3 percent during the 1960-to-80 period to an average of 3.7 percent per year since 1980 (U.S. National Science Foundation 2010; U.S. Census Bureau 2011). Similarly, the time series of U.S. patent data indicate the process of knowledge accumulation has accelerated. After essentially no growth between 1940 and 1960, the annual number of patents awarded increased 32 percent over the 1960-to-1980 period. Since 1980, patent activity has risen sharply, nearly quadrupling by 2010 (U.S. Patent and Trade Office). Education statistics also demonstrate that the stock of human capital in the United States has been growing rapidly. Less than 4 percent of the population 25 years and older were college graduates in 1940, but the proportion with college degrees had more than tripled by 1980, and approached 29 percent by 2009.

Benchmarking the U.S. Knowledge Economy Using OECD Metrics

Given the long-standing emphasis that the OECD has placed on the important role of knowledge and technology for economic growth (OECD 1996), the organization began to systematically compile a set of indicators relating to the knowledge economy in the 1990s and has continued to maintain databases and analyze the trends in these data series for its member countries (including the United States). (See, for example, the latest (2009) edition of the *OECD Science, Technology, and Industry Scoreboard*.)

These data allow comparison of knowledge economy metrics among the 30+ advanced economies tracked by the OECD. For example, the OECD information shows that in absolute terms, the United States spends more on R&D than any other country but is ranked seventh in terms of R&D expenditures as a proportion of GDP and ranked below average for growth in R&D spending over the 1995-to-2005 period (OECD 2007). Looking at the human side of the knowledge economy, OECD data indicate that the United States ranked 12th out of 27 reporting countries on the share of jobs in science and technology fields in 2008, and it ranked near the bottom for growth in science and technology jobs over the 1997-to-2007 period (OECD 2009).

In addition to tracking knowledge economy-related variables, the OECD also established a formal definition of a "knowledge-based" economy and developed two concepts directly related to this newly defined construct:

- "Knowledge-based" industries were defined as those with the following characteristics: (1) a high level investment in innovation, (2) intensive use of technology, and (3) a highly educated workforce.

  The OECD estimates the gross value added produced by these "knowledge-based" industries. Based on 2004 data, the United States ranked fifth among the 29 advanced economies for which the metric was available, mostly due to its large knowledge-intensive services sector. Like many other advanced economies, the relative importance of the knowledge-intensive manufacturing sector in the United States has been declining steadily in recent years. This reflects the continued shift of manufacturing to less-developed countries and the increasing importance of services in advanced economies. According to OECD estimates, the United States ranked 17th in terms of the share of total gross value added produced by the knowledge-intensive manufacturing sector (OECD 2007).

- “Investment in knowledge” was defined as expenditures for activities that enhance existing knowledge, create new knowledge, and distribute knowledge. Statistically this concept was defined as the sum of expenditures on R&D, higher education, and software.

  The United States ranked first for investment in knowledge as a proportion of GDP in 2004 among the 18 advanced economies for which the OECD made estimates. Investment in knowledge has been increasing in all but one of the reporting countries, with the United States jumping from 5.7 percent in 1997 to 6.6 percent in 2004 (OECD 2007).

Benchmarking the U.S. Knowledge Economy Using Composite Indexes

Composite indicators that compare country performance are increasingly recognized as a useful tool in policy analysis and public communication. Such composite indicators provide summary comparisons among countries that can be used to illustrate complex and sometimes elusive issues in wide-ranging fields. It often seems easier to interpret composite indicators than to identify common trends across many separate indicators, and they have also proven useful in benchmarking country performance. A composite indicator is formed when individual indicators are compiled into a single index on the basis of an underlying model. A composite indicator should ideally measure multidimensional concepts which cannot be captured by a single indicator. The pros and cons of such indexes have been widely debated (see OECD 2008 for a useful summary), but they are popular and widely used in the analysis and evaluation of a myriad of issues.

A number of composite indexes have been developed that provide comparative information for many nations about their potential, capacity, performance in the global knowledge economy. The World Bank’s *Knowledge Index* and *Knowledge Economy Index* obviously have been designed expressly for that purpose. Many of the other indexes, while explicitly focusing on different issues such as economic development, high technology, innovation, or competitiveness, produce information that provides useful insights relating the knowledge economy. Two examples of such indexes are discussed after the World Bank indexes. They have a somewhat broader focus than the World Bank measures but have subindexes that relate directly to important dimensions of the knowledge economy.

World Bank Indexes

The Knowledge Index and *Knowledge Economy Index* were developed by the World Bank to benchmark “the preparedness to compete in the knowledge economy” (World Bank 2009). They are updated annually, and the latest 2009 report produced indexes for 146 countries. The indexes are based on 109 variables grouped according to what the World Bank terms “the four pillars of the knowledge economy” framework: education and human resources, the innovation system, information and communication technology, and the economic and institutional regime.

The Knowledge Index (KI) is constructed as a measure of a country’s ability to “generate, adopt, and diffuse knowledge.” It is calculated as the simple average of normalized scores for the variables in three of the knowledge economic pillars: education, innovation, and information and communication technologies. Separate subindexes are reported for each of the pillars. The Knowledge Economy Index (KEI) adds variables relating to the fourth pillar — the economic and institutional regime — to assess whether economic incentives and institutions are conducive for the effective use of knowledge to promote economic growth. The KEI is an aggregate index that attempts to represent the overall level of development of a country or region toward the knowledge economy. The KEI is calculated from the normalized performance scores of a country or region on all four pillars of the knowledge economy.

The 2009 KI ranks the United States 10th among the 146 nations, with Sweden ranked first and Western European countries holding seven of the top 10 rankings. The U.S. ranking is down from third in 1995 and fifth in 2000. For the broader KEI, the United States fared somewhat better, ranking ninth for the 2009 index. But this was again lower than the rankings in earlier years: second in 1995 and sixth in 2000. Examination of the subindexes shows that the drop in overall KEI ranking from 1995 to 2009 was primarily the result of a big decline in relative scoring for information and communications (from first to 14th), a substantial decline in the score for the economic and institutional regime (ninth to 15th), and much smaller losses for the other two pillars: fourth to sixth for the innovation system and 12th to 13th for education and labor force.

Global Competitiveness Index
For more than three decades, the World Economic Forum has annually produced a report that analyzes the many factors needed for countries to achieve economic growth and long-term prosperity. The Forum's stated goal of this exercise is to provide benchmarking tools to business leaders and policymakers for the evaluation of the competitiveness of their economies. Since 2005, its competitiveness analysis has been based on the *Global Competitiveness Index* (GCI), a composite index that incorporates more than 100 variables measuring the microeconomic, macroeconomic, institutional, and social factors associated with national competitiveness. The analysis groups the individual indicators to produce subindexes based on what the Forum terms the "12 pillars of competitiveness," with the overall GCI based on a weighted average of the subindexes. The 2010-11 report included GCI scores for 139 countries (Schwab 2010).

Among the "12 pillars of competitiveness," three of the pillars relate most directly to the knowledge economy: higher education and training; technological readiness; and innovation. In the 2010-11 report, the United States ranked first on innovation, but ninth for the higher education and training component, and 17th for technological readiness factors. In the first GCI (2005-06), the U.S. subindex score for higher education and training ranked fifth. Examination of the detailed scores shows the biggest negative factor was the quality of secondary education, particularly in math and science. The 2010-11 ranking for technology readiness was also substantially lower than the number-eight ranking in the 2005-06 analysis, primarily due to issues relating to the areas of technology transfer and the U.S. Internet system.

Global Innovation Index
INSEAD, a top-ranked international business school with campuses in Europe and Asia, produces the *Global Innovation Index* (GII), a composite index measuring the innovation potential and performance of economies around the world. The latest (2011) report includes 125 countries, and provides not only the overall GII results but also scores and rankings for each of the 20 components included in the analysis (Dutta 2011). Since the concept of innovation is closely tied to the knowledge economy, the GII has several components that focus directly on

factors important to the knowledge economy — primary and secondary education, higher education, research and development, knowledge workers, knowledge creation, knowledge impact, and knowledge diffusion. The latest benchmarking exercise by INSEAD gave the United States relatively high — but not top — rankings for most of these seven components. The rankings for the two education components were much weaker, however, with primary and secondary education ranking 36th and higher education ranking 46th.

Synthesis of the Results

Three prestigious organizations have developed country-level composite indexes relating to the knowledge economy. The indexes have been constructed for different purposes, use different data sets, and include somewhat different collections of countries. Despite differences in methodologies and coverage, the results of all three provided relatively similar assessments of how the United States is faring in the global knowledge economy.

All three studies give the U.S. economy very good but not top ratings, and comparisons of the results over time show a pattern of decline for the United States relative to the top-ranked economies. Looking at the individual dimensions of the knowledge economy, the United States had its highest rankings for factors relating to R&D and innovation and its lowest rankings for the education and technological readiness components. The assessment of the U.S. knowledge economy based on the OECD metrics is consistent with the results from the composite indexes.

BENCHMARKING ARIZONA'S KNOWLEDGE ECONOMY

Many of the indicators used to monitor the knowledge economy at the national level are also available at the state level. This section looks at some of the individual knowledge-related metrics and also examines the results of three composite indexes related to the knowledge economy in order to assess the status of Arizona's knowledge economy relative to other U.S. states. In particular, Arizona is compared to eight western states that are primary economic competitors: California, Colorado, Nevada, New Mexico, Oregon, Texas, Utah, and Washington.

Knowledge Workers

Using occupational data, Arizona's knowledge workers made up a slightly smaller share (29 percent) of total employment than in the national economy (31 percent) in 2010. This put the state at 23rd out of the 50 states in terms of the proportion of knowledge workers. The percentage was highest in Massachusetts (37 percent) and lowest in Nevada (22 percent). Rankings for Arizona and eight other western states are presented in the top line of Table 3. Arizona ranked fifth among the nine western states, only slightly higher than three others. Colorado ranked highest at seventh.

Based on industrial data, Arizona's percentage of employment in knowledge-based industries (33.5 percent) was only marginally less than the U.S. average (34.0 percent). The largest proportion of knowledge workers are in knowledge-creation industries followed by health care, with the proportions in Arizona nearly equal to the national average (see Table 4). The makeup of Arizona's knowledge-based industries is different than the national average, however, with the shares higher in Arizona in high-tech manufacturing and financial services, but lower in high-tech services and professional services.

TABLE 3
RANKINGS RELATIVE TO THE 50 U.S. STATES FOR ARIZONA AND EIGHT OTHER WESTERN STATES FOR SELECTED KNOWLEDGE ECONOMY METRICS

	AZ	CA	CO	NV	NM	OR	TX	UT	WA
Proportion of Knowledge Workers, Calculated by Occupation (2010)*	23	12	7	50	24	16	28	27	11
Proportion of Science and Engineering Doctorates in Civilian Workforce (2006)**	38	9	8	49	2	15	30	18	7
Research and Development Activity as a Proportion of GDP (2007)**	25	7	11	48	1	12	29	21	4
Patent Awards Per Capita (2008)**	19	4	10	30	29	7	20	16	2
Proportion of Population 25 years and Older with a College Degree (2008)***	31	14	2	45	35	18	30	17	11
Proportion of Population 25 years and Older with an Advanced College Degree (2008)***	25	13	7	45	15	17	35	24	12
K-12 Public Schools Current Expenditures as a Proportion of GDP (FY2008)^	39	37	44	49	14	41	32	42	47
Total Higher Education Expenditures as a Proportion of GDP (FY2009)^	30	29	43	50	7	19	39	6	40
8th Grade Math Proficiency NAEP Test Scores (2007)^^	38	41	11	42	49	22	23	29	15
Averaged Freshman Graduation Rates for Public Secondary Schools (FY08)^^	41	39	30	50	45	24	35	33	38

Sources:
* Calculated from data from the U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment Statistics.
** Calculated from data from the U.S. National Science Foundation, *Science and Engineering Indicators 2010*.
*** Calculated from data from the U.S. Census Bureau, *2011 Statistical Abstract.*
^ Calculated from data from the U.S. Department of Education, National Center for Educational Statistics.
^^ Calculated from data from the U.S. Department of Education, National Assessment of Education Progress.

TABLE 4
KNOWLEDGE ECONOMY EMPLOYMENT BY INDUSTRY
ARIZONA AND UNITED STATES

	Arizona, 2009	Share of Total, 2009 Arizona	Share of Total, 2009 United States	Change in Share, 2000 to 2009 Arizona	Change in Share, 2000 to 2009 United States
TOTAL OF ALL SECTORS	2,480,784				
TOTAL KNOWLEDGE-BASED	831,494	100.0%	100.0%		
High-Technology Manufacturing*	51,364	6.2	3.5	-5.0	-1.6
High-Technology Services**	68,372	8.2	9.4	0.4	0.8
Knowledge Creation***	268,456	32.3	32.5	4.1	1.5
Information Technology***	23,174	2.8	3.3	-0.3	-1.4
Other Knowledge-Based***:					
Professional Services	96,753	11.6	14.5	-3.7	-0.5
Financial Services	131,840	15.9	13.6	0.0	-0.5
Health Care	191,535	23.0	23.2	4.5	1.9

Notes (see Appendix Table A-1):
* Six manufacturing industry groups included in the BLS definition of level I high-technology industries
** Ten services industry groups included in the BLS definition of level I high-technology industries
*** Industry groups included in the DMWD definition, excluding any overlap with the BLS high-technology groups

Source: U.S. Department of Commerce, Census Bureau: *County Business Patterns* and *Government Employment and Payroll* (2000 and 2009).

Between 2000 and 2009, employment of knowledge workers increased more other workers in Arizona and nationally. The knowledge worker share rose from 31.7-to-33.5 percent in Arizona. The national increase in share was a bit higher, from 31.8-to-34.0 percent. In both Arizona and the nation, employment growth was especially high in the knowledge creation and health care categories. In contrast, employment growth was relatively slow in the high-tech manufacturing category. In Arizona, employment decreased in professional services, mostly in the accounting services industry group, which has a time series of erratic employment figures.

Benchmarking Arizona's Knowledge Economy Based on Selected Knowledge Economy-Related Metrics

Arizona ranks near the middle of the states on the knowledge economy's share of employment. This section looks at how the state compares in terms of other metrics associated with the knowledge economy. The rankings for all nine metrics discussed in this section are presented in Table 3.

Three indicators often are used to monitor knowledge creation. The first two measure inputs to R&D and the third is an output measure:

- **The proportion of Ph.D. scientists and engineers in the overall workforce**, an indicator of human capital input. Arizona ranked substantially below average (38th among the 50 states) and below all but one of its western "competitor" states. In comparison, four of the other eight western states ranked in the top 10, with New Mexico second, due to the Los Alamos and Sandia National Labs.

- **R&D expenditures as a proportion of state GDP**. Arizona ranked in the middle of the states (25th) in terms of R&D activity but again was below average relative to its western "competitor" states. New Mexico ranked first. Washington, California, Colorado and Oregon were all in the top 12.

- **U.S. patents awarded per capita**. Arizona ranked above average nationally (19th) but ranked sixth among the nine western states, four of which ranked in the top 10.

Turning to metrics relating to human capital, the first set measures the educational attainment of the state's adult population:

- **The proportion of the population 25 years and older with at least a bachelors degree**. Arizona ranked 31st among the 50 states and below all but two of the other eight western states.

- **The proportion of the population 25 years and older with an advanced degree**. Arizona ranked somewhat higher nationally (25th) but still was higher than only two of its western "competitor" states.

In reality, these two measures overstate Arizona's human capital since many of its university graduates are retired. (A number of well-educated individuals migrate to Arizona when they retire.) Colorado was in the top 10 on each measure, with California and Washington in the top 15 on each.

The next indicators relate to the level of resources allocated to the creation of human capital, measured by spending for K-12 education and higher education as proportions of the state's GDP:

- **Expenditures for current operations (excluding capital outlays) for public K-12 education as a proportion of GDP**. Arizona ranked 39th among the 50 states, but most of the western "competitor" states also ranked between 37th and 49th. Only New Mexico ranked in the upper half of U.S. states on this K-12 spending measure. These expenditure data refer only to public school funding. Arizona and most of the other western states have relatively small numbers of students attending private schools. They would rank even lower based on total school expenditures.

- **Total higher education expenditures as a proportion of GDP**. Arizona ranked 30th in terms of resources allocated to funding higher education institutions. Four western states ranked lower, but Utah and New Mexico ranked in the top 10.

The final metrics relate to student performance. The first is an indicator of student performance at the end of elementary school, and the other is an output measure for the states' secondary schools:

- **Proficiency in eighth grade mathematics**. Arizona ranked substantially below average nationally (38th). Three western states ranked lower. Only three of the nine western states ranked in the upper half of all states, with Colorado the highest at 11th. (Arizona also was below average in science proficiency, but the ranking is not specified since scores were not available for all 50 states.)

- **Averaged freshman graduation rates for public secondary schools**. Used as a measure of the states' high school performance, eight of the nine western states ranked in the lower half of the 50 states, with Arizona again way below average at 41st. However, shortcomings exist in this measure of high school graduation.

Arizona appears poorly prepared to compete in the knowledge economy, with a median rank of 31st across the 10 measures included in Table 3. Arizona ranks highest — albeit around the middle of the states — with respect to some of the indicators that are proxies for current performance: share of knowledge workers, patent production, and research and development activity. However, several of its regional peers had very high rankings for these same variables. Arizona ranked between fifth and eighth among the nine western states on each of the measures of current performance.

For most of the metrics associated with the state's human capital creation, Arizona ranked between 30th and 41st. Since many of its eight western "competitor" states also ranked poorly, Arizona ranked between fourth and seventh among its regional peers.

Knowledge Economy Composite Indexes

Just as with international comparisons, a growing number of composite indexes have been developed that compare the 50 U.S. states. This section looks at results from three such studies that provide comparisons among the states with respect to their potential, capacity, and performance in the knowledge economy. The rankings for Arizona and eight other western states from these analyses are listed in Table 5.

The 2001 Knowledge-Based Economy Index

No current ongoing studies provide interstate rankings explicitly aimed at the knowledge economy. The Milken Institute did produce what was termed the *Knowledge-Based Economy Index* (KBEI), with the latest set of rankings released in 2001 (Milken Institute 2001). The index was based on 12 criteria "that Milken Institute research has determined are critical to a region's future high-tech growth," including measures of educational attainment, R&D and patent activity, and business start-up related activities. (The Milken Institute treated "high-tech" as equivalent to "knowledge based" in this study. In fact, the confusion among terms was even broader as the press release issued with the 2001 KBEI also kept referring to the "new" economy rather than the "knowledge-based" economy.)

The 2001 KBEI, which was based on 1990s data, ranked Arizona 13th among the 50 states. This was sixth among the nine western reference states, with California ranked second, Colorado third, and Washington seventh. Four of the group — Utah, Texas, Arizona, and Oregon — were bunched in the 11th through 14th slots, and only Nevada (37th) ranked in the bottom half of the states.

TABLE 5
RANKINGS RELATIVE TO THE 50 U.S. STATES FOR ARIZONA AND EIGHT OTHER WESTERN STATES FOR THREE KNOWLEDGE ECONOMY COMPOSITE INDEXES

	AZ	CA	CO	NV	NM	OR	TX	UT	WA
2001 Knowledge-Based Economy Index	13	2	3	37	21	14	12	11	7
State Technology and Science Index:									
2010 Overall	15	4	3	46	18	21	19	5	6
2002 Overall	18	3	2	42	20	23	14	9	6
2010 Research and Development Inputs Subindex	15	4	5	43	10	14	28	13	6
2010 Technology and Science Workforce Subindex	20	7	5	50	25	32	10	8	4
2010 Human Capital Investments Subindex	32	13	3	50	25	27	38	8	21
New Economy Index:									
2010 Overall	20	7	9	30	32	14	18	12	2
1999 Overall	10	2	3	21	19	15	17	6	4
2010 Technology Innovation Capacity Index	18	3	6	43	10	14	23	20	2
2010 Digital Economy Subindex	25	6	14	20	47	8	24	18	9
2010 Knowledge Jobs Subindex	27	13	11	45	36	21	32	15	8

Sources: Milken Institute, *Knowledge-Based Economy Index* (2001); DeVol et. al., *2010 State Technology and Science Index* (2011); DeVol et. al., *2002 State Technology and Science Index* (2002); Atkinson and Andes, *2010 New Economy Index* (2010); Atkinson et. al., *The State New Economy Index* (1999).

The 2010 State Technology and Science Index

Probably the most widely followed state composite index related to the knowledge economy is the Milken Institute's *State Technology and Science Index* (STSI) (DeVol, Klowden, and Yeo 2011). First produced in 2002, the study evaluates each state's science and technology capabilities. The latest version, the 2010 STSI, is constructed from 79 individual indicators classified into five groups with their own composite indexes. Three of these groups relate most closely to the knowledge economy: human capital investment; R&D inputs; and technology and science workforce. The rankings for the overall 2010 STSI and the three subindexes are presented in Table 5, along with the overall rankings for the original 2002 STSI. (The indexes in the 2010 study are not directly comparable with those produced in earlier years. See the earlier STSI report (DeVol et. al. 2002) for the differences in methodologies.)

The 2010 overall STSI ranked Arizona 15th among the 50 states, placing it slightly higher than its score in the 2002 study. This is similar to its rank in Milken's earlier and less sophisticated Knowledge-Based Economy Index. With four of its peers ranked in the top six, led by Colorado at third, Arizona still fell in the middle of the nine states in the western reference group.

Arizona received the same 15th ranking for the subindex relating to R&D inputs, but six of its western peers ranked higher on this dimension of the knowledge economy, again including three states in the top six. On the technology and science workforce subindex, Arizona ranked 20th, but only seventh among the nine-state peer group, of which five ranked in the top 10.

Arizona's worst performance in the 2010 study was in the area of human capital investments, where it ranked in the bottom half of all states at 32nd. Most of its western peer states also ranked lower on this subindex — consistent with the generally poor results for the set of individual human capital-related indicators discussed previously — but Arizona still ranked seventh in the peer group.

The 2010 New Economy Index

The Information Technology and Innovation Foundation, a Washington, D.C. think tank, produces another widely quoted composite index, the *New Economy Index* (NEI). This index has been developed "to measure to what degree the structure of each state's economy matches the ideal structure of the New Economy" (Atkinson and Andes 2010, p. 5). The analysis is based on 26 individual indicators grouped according to the five primary dimensions that "best capture what is new about the New Economy:" knowledge jobs; globalization; economic dynamism; transformation to a digital economy; and technological innovation capacity. The rankings for the overall 2010 NEI and its knowledge jobs, digital economy, and innovation capacity subindexes are presented in Table 5. The overall rankings for the original 1999 NEI are also listed for illustrative purposes. (The 1999 New Economy Index was produced by the Progressive Policy Institute (Atkinson et. al. 1999) and based on somewhat different data and methodology.)

Arizona ranked 20th among the 50 states in the 2010 overall NEI, a big drop from 10th place in the 1999 version of the Index. This ranking placed it below six of the eight western peer states.

Looking at the subindexes, Arizona ranked highest (18th) on the dimension of technological innovation capacity, but still ranked in the lower half of the nine western states with three of its peers among the top six states. Arizona ranked in the middle of all states (25th) with respect to the transformation to the digital economy subindex, but that placed it below seven of its eight western peer states. Its worst showing was for the knowledge jobs subindex (27th), which again placed in the bottom half of the nine western states.

Synthesis

Overall, the assessment of Arizona's standing in the knowledge economy based on the composite indexes is more positive than the one based on the set of individual indicators. The composite index studies do not show that the state is near the top tier of knowledge economy states, but Arizona ranks 15th overall on the STSI and 20th overall on the NEI. Both the analysis of individual metrics and the composite index results show that Arizona's primary weakness is in the human capital area, an issue that will be discussed in the next section.

IMPROVING ARIZONA'S CHANCES TO SUCCEED IN THE KNOWLEDGE ECONOMY

The possibility that America has lost its position of leadership and is in danger of falling farther behind in the global knowledge economy has been of increasing concern. A series of studies have documented this decline (see, for example, Task Force on the Future of American Innovation (2006) or National Academy of Sciences (2007)). A broad spectrum of public and private organizations has called for steps to strengthen the competitive position of the nation in the global knowledge economy of the 21st century.

Taking a more local perspective, assessments of Arizona's place in the knowledge economy show that it is at best in the second tier of states and has been slipping in recent years. The state does have some of the basic ingredients needed to increase the knowledge intensity of the Arizona economy, but much more is needed to successfully compete with other states (and more generally in the global knowledge economy).

Commitment

Strong and effective leadership is needed from both elected officials and the business community. To be effective, leaders must themselves be convinced that having a knowledge-based economy is important and must successfully build support first among major stakeholder groups and then among the public and the business community in general. A widely held belief among the state's citizens in the importance of a knowledge economy to Arizona's future prosperity is crucial for success. Also vital is the recognition by both the leaders and the public that the state must compete in terms of factors important to success in the knowledge economy, which will mean moving away from the state's traditional approach to economic development that focused on minimal regulation and low costs of doing business.

Improve Education and Training

A strong commitment to education and human capital development is a fundamental building block of the knowledge economy. The evidence presented in the previous section indicates that education should be the area of most concern to those interested in fostering Arizona's knowledge economy.

K–12 Education
The educational achievement and attainment of the state's students needs to be improved. Funding levels are among the lowest in the nation and should be increased, but providing more resources to the educational system is not the only policy action necessary. The focus should be on results. For the quality of education needed for success in the knowledge economy, improvements in math and science education are particularly important, but many other reforms of the current system are also needed, including changes to other aspects of the curriculum, the development and enforcement of higher standards and graduation requirements, and increased efforts to reduce dropout rates.

Higher Education
Colleges and universities, particularly research universities, have a key role in the knowledge economy, both producing the educated and skilled workers that are needed and as major players in the production and distribution of knowledge.

To compete in the global knowledge economy, Arizona needs a college and university system that produces well-trained graduates able to compete with graduates of the best schools in the nation and that has capacity to provide access to all qualified Arizona residents, rather than a system that does the best job it can with shrinking resources. In particular, the recent Milken report on technology-based economic development in Arizona (Klowden et. al. 2009) emphasizes the need to expand programs in engineering and applied sciences, especially in those fields in high demand by local employers, while utilizing two-year colleges to train local workers for entry-level positions.

The state's universities have been working hard to increase their activities related to the production and distribution of knowledge, but continued expansion of the universities' research and technology transfer activities are another key prerequisite for Arizona to compete in the knowledge economy. Both the size and the quality of university research programs are important. Universities with the greatest economic impact are generally those with high-quality research programs.

Expand Efforts to Attract, Retain, and Expand Knowledge-Based Industry in Arizona
With the state suffering through the aftermath of the worst recession in the last 70 years, the short-term goal of all those trying to resuscitate the Arizona economy is to increase economic activity and to get Arizona's unemployed back to work. But in the longer run, the focus of economic development activities in the state should be on the knowledge economy, given its key role in producing economic growth and prosperity.

Some of the economic development activities in Arizona are already aimed in this direction, such as the Office of Innovation and Technology in the new Arizona Commerce Authority, the Governor's Council on Innovation and Technology, and technology industry groups. Such efforts need to be expanded and multiplied in the future.

The activities of the Science Foundation of Arizona and other groups in the state that encourage and support research and development activities should be expanded. Ways need to be found to increase the availability of venture capital and other forms of financing for startups and expanding firms, an issue always mentioned as a detriment to the state's economic development (Klowden et. al. 2009).

Emphasize Comparative Advantages

High-tech clusters have been growing in the metro Phoenix and Tucson areas around Arizona's universities. Efforts should aim at further developing the technology clusters. Multiple research studies over the years have shown clusters are an essential component of high-tech success (Klowden et. al. 2009). Once they reach critical mass, clusters lure in additional companies eager to take advantage of access to capital, technology, and workers. Workers, too, are drawn by higher-paying jobs and access to a wide range of employment opportunities in one geographic location.

Solar and wind energy are often mentioned as areas in which the state has a comparative advantage. A recent ASU study identified Arizona as the state with the best potential for the production and export of solar energy (Croucher 2010), and both wind farms and solar energy plants are being constructed around the state. Generation activities should be expanded, and other segments of these industries — research and development, manufacturing, etc. — should be encouraged.

Arizona should also look for ways to support and encourage its existing base of technology industries. Intel Corporation recently announced that it will build a new microprocessor plant in Chandler, but other technology firms have disappeared or moved operations elsewhere. The retention and expansion of existing knowledge-based firms is important to the success of Arizona's knowledge economy. The transformation of former low-technology industries into knowledge-intensive businesses through the adoption of new technologies and the upgrading of their workforce should be another goal of efforts to further Arizona's knowledge economy.

Quality of Place

Characteristics of the knowledge economy and advances in information and communications technology have reduced the economic importance of proximity to markets and raw materials, so that other characteristics of regions have become more important in the locational decisions of businesses and individuals. For businesses, important factors include the following:

- A critical mass of complementary firms: those in the same or related industries and suppliers.
- A sufficiently large supply of skilled workers.
- Adequate infrastructure (most directly IT infrastructure but other aspects such as transportation and utilities are also important).
- The presence of research universities.

For individuals, and indirectly for businesses, quality-of-life factors are also important, such as housing, schools, personal safety, and geographic and environmental considerations.

Some of these issues are not amenable to policy decisions — for example, whether the area is located in the desert or near the ocean — but others such as the quality of schools or the adequacy of the regional transportation system are determined (or at least can be affected) by public policy decisions. As a general rule, decision makers for knowledge-based firms and knowledge workers are more interested in quality than low cost. While knowledge-based industries are just as interested as everyone else in efficiency, places that try to compete based on low cost and low quality will not be successful in the knowledge economy.

Philosophical Issues

Arizona is currently struggling to recover from a severe recession, and the poor economic environment has had dramatic impacts on the whole gamut of public programs. State and local government budgets have been cut significantly and will continue to be under tremendous pressure. Without changes to the state's tax and revenue system that will produce more revenue, further spending cuts are probably more likely than any additional spending to expand and/or improve public programs.

In addition, Arizona is a fiscally conservative state; strong antitax and smaller-government sentiments exist among elected officials, the business community, and the public. A supermajority of legislators is needed to approve tax increases making it very difficult to raise revenues, and there have been continuing efforts to implement more restrictive limits on state spending. All these reasons will make it very difficult for Arizona to make improvements in and/or start the programs needed to successfully compete in the knowledge economy.

Some of the recommendations would involve actions that would target particular knowledge-intensive industries for public support. Such policies are termed "industrial policy" by economists, and in general economists are critical of such actions because they believe free-market forces should be sufficient to guide resources to their highest valued use. They further argue that there is no reason to believe that government can do better than the market in "picking winners." Many elected officials, business persons, and members of the public in Arizona share these views. Another argument against such industrial policy has to do with the way it often works in practice, with special interests having undue influence. More generally, many are simply opposed to any expansion of government on philosophical grounds.

As discussed previously, however, the public returns from the creation, diffusion, and use of knowledge to society are much higher than the private returns because of spillovers or external economies associated with knowledge. When such external economies exist, the free-market outcome results in too few resources being allocated to knowledge-related activities. Those in favor of stimulating Arizona's knowledge economy would assert that this suboptimal result should counterbalance a general aversion to government intervention and strengthens the argument in favor of programs to attract and retain knowledge-based industries.

The Bottom Line

Going back many years, the goals of economic development activity in the state have been to attract and expand high value-added activities and to create high-paying jobs. Efforts were centered broadly on manufacturing, with a subemphasis on high tech firms. Over time with the decline of domestic manufacturing, the focus has shifted to what in knowledge-economy terminology would be termed knowledge-based or knowledge-intensive industries, though still often referred to as high technology.

Unfortunately, these efforts have met with limited success. Like many other high-tech states, the concentration of high-technology activities in Arizona has continued to decline, so that Arizona no longer has a high-technology presence much different than the national average. In addition, Arizona continues to have a narrow base of high-technology activities. Only two activities with substantial employment — manufacturing of aerospace products and manufacturing of semiconductor and other electronic components — have a much greater relative presence in Arizona than the national average (Rex 2008). Knowledge workers in Arizona make up a slightly smaller share of the total civilian workforce than in the national economy, putting the state at 23rd out of the 50 states and with a smaller share than the most of its “competitor” states in the West.

As a result, per capita income levels in Arizona remain far below the national average and also below the levels in most of its “competitor” states. What is worse for the state’s economic future is the prospect that this income gap will continue to widen. The University of Arizona’s long-term economic forecasts for the state project that “per capita personal income relative to the nation will continue its downward slide from 84% today to nearer 77% thirty years from now” (Vest 2010).

The creation, distribution, and application of knowledge — the bases of the knowledge economy — have been the most important factors driving the dramatic rise in living standards in the United States. Barring unforeseen game-changing phenomena, the knowledge economy will continue to be the key driver of economic growth and prosperity in the future. Fundamental changes in the Arizona economy appear to be needed if the state is to fully participate in the global knowledge economy of the 21st century.

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APPENDIX TABLE A-1
INDUSTRY-GROUP-BASED DEFINITION OF THE KNOWLEDGE ECONOMY

NAICS

High-Technology
(As Defined by the U.S. Bureau of Labor Statistics*)

Manufacturing

3254 Pharmaceuticals and Medicines
3341 Computers and Peripheral Equipment
3342 Communications Equipment
3344 Semiconductors and Electronic Components
3345 Navigation, Measuring, Electromedical and Control Instruments
3364 Aerospace Products and Parts

Services

5112 Software Publishers
5152 Cable and Other Subscription Programming
5161 Internet Publishing and Broadcasting
5179 Other Telecommunications
5181 ISP and Web Search Portals
5182 Data Processing and Related Services
5191 Other Information Services
5413 Architectural and Engineering Services
5415 Computer systems Design and Related Services
5417 Scientific Research and Development Services

Knowledge Economy: In Addition to the Industry Groups Included in High Technology
(As Defined by the Massachusetts Department of Workforce Development)**

Knowledge Creation

3231 Printing and Related Support Activities
6111 Elementary and Secondary Education
6112 Junior Colleges
6113 Colleges and Universities
6114 Business, Computer and Management Training
6115 Technical and Trade Schools
5191 Libraries and Archives (Other Information Services)
Government***
  K-12 Education
  Higher Education
  Other Education
  Local Libraries

Info Technology

3343 Audio and Visual Equipment Manufacturing
3346 Manufacturing and Reproducing Magnetic and Optical Media
3351 Electric Lighting Equipment Manufacturing
3352 Household Appliance Manufacturing
3353 Electrical Equipment Manufacturing
3359 Other Electrical Equipment and Component Manufacturing
5171 Wired Telecommunications Carriers
5172 Wireless Telecommunications Carriers
5173 Telecommunications Resellers
5174 Satellite Telecommunications
5175 Cable and Other Programming Distribution

Knowledge-Based

Professional Services
5411 Legal Services
5412 Accounting Services
5416 Management and Technical Consulting Services
5418 Advertising and Related Services
5511 Management of Companies
Financial Services
5211 Monetary Authorities
5221 Depository Credit Intermediation
5222 Nondepository Credit Intermediation
5223 Activities Related to Credit Intermediation
5231 Security and Commodity Investment Activities
5232 Security and Commodity Exchanges
5239 Other Financial Investment Activities
5241 Insurance Carriers
5242 Agencies and Brokerages and Other Insurance
Health Care
3391 Medical Equipment and Supplies Manufacturing
6211 Offices of Physicians
6212 Offices of Dentists
6213 Offices of Other Health Professionals
6214 Outpatient Health Services
6215 Medical and Diagnostic Laboratories
6221 General and Surgical Hospitals
6222 Psychiatric and Substance Abuse Hospitals
6223 Specialty Hospitals

Notes:
* Definition in Hecker (2005).
** Classification based on Massachusetts Department of Workforce Development (2007). Some additional NAICS industries in the industry groups specified by the MDWD have been included — in particular in the health care sector. Some equivalent categories from the government sector, which are not classified in this way in NAICS, have also been added.
*** Conceptually, equivalent knowledge-intensive parts of the government sector - e.g. government hospitals -should be included. Because of data limitations, only state and the local education and library/archives were included in the analysis.

THE PRODUCTIVITY AND PROSPERITY PROJECT

The Productivity and Prosperity Project: An Analysis of Economic Competitiveness (P3) is an ongoing initiative begun in 2005, sponsored by Arizona State University President Michael M. Crow. P3 analyses incorporate literature reviews, existing empirical evidence, and economic and econometric analyses.

Enhancing productivity is the primary means of attaining economic prosperity. Productive individuals and businesses are the most competitive and prosperous. Competitive regions attract and retain these productive workers and businesses, resulting in strong economic growth and high standards of living. An overarching objective of P3's work is to examine competitiveness from the perspective of an individual, a business, a region, and a country.

THE CENTER FOR COMPETITIVENESS AND PROSPERITY RESEARCH

The Center for Competitiveness and Prosperity Research is a research unit of the L. William Seidman Research Institute in the W. P. Carey School of Business, specializing in applied economic and demographic research with a geographic emphasis on Arizona and the metropolitan Phoenix area. The Center conducts research projects under sponsorship of private businesses, nonprofit organizations, government entities and other ASU units. In particular, the Center administers both the Productivity and Prosperity Project, and the Office of the University Economist.

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