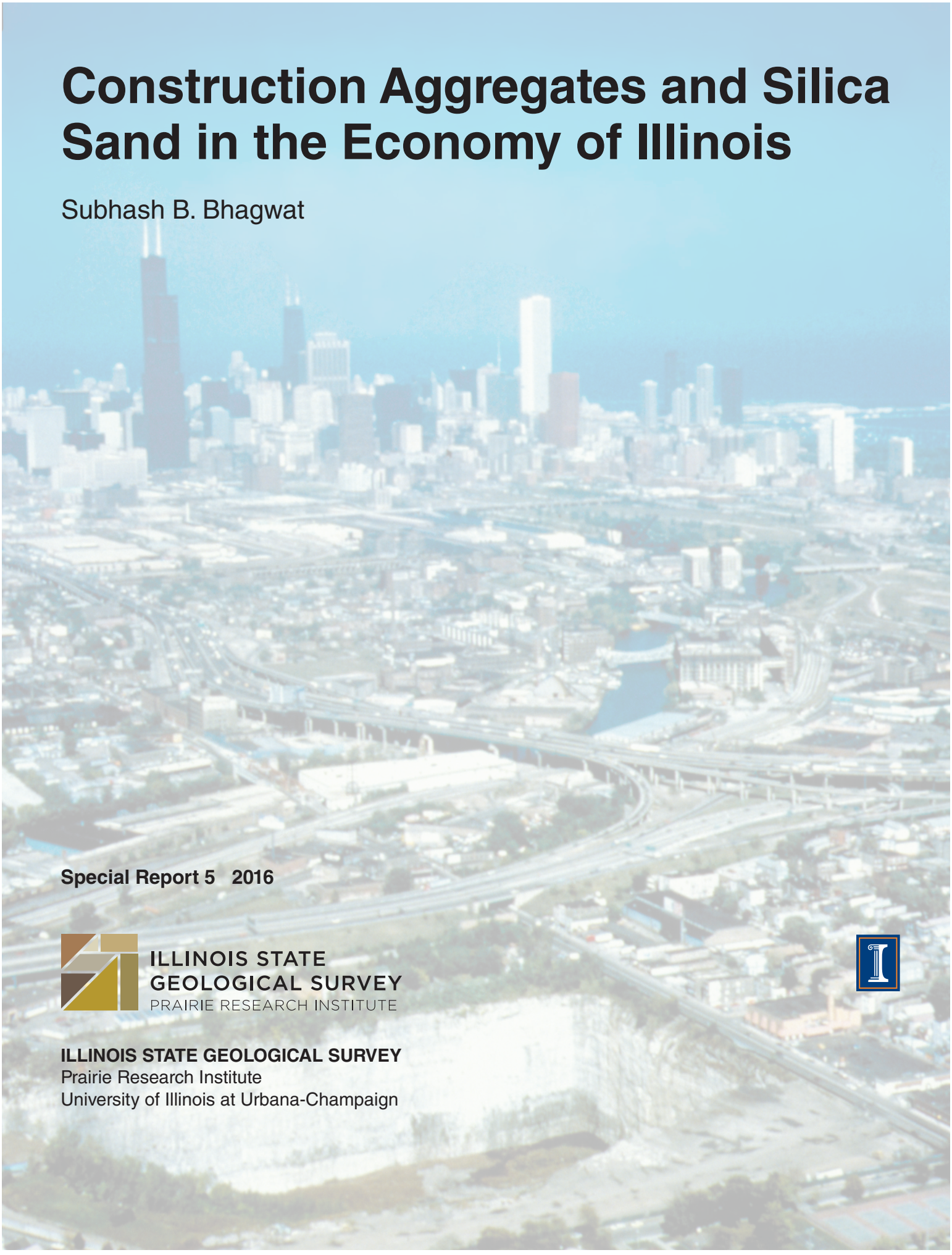
Construction Aggregates and Silica Sand in the Economy of Illinois

Subhash B. Bhagwat



Special Report 5 2016

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Front cover: *This quarry* (*lower center*) *on Chicago's south side has been overrun by the development of buildings and highways whose existence would not have been possible without crushed stone extracted from this or similar quarries in the area.* (*Photograph by Joel M. Dexter.*)

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Prairie Research Institute
University of Illinois at Urbana-Champaign
615 E. Peabody Drive
Champaign, Illinois 61820-6918
http://www.isgs.illinois.edu

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ABSTRACT

It is common to find studies that describe trends in production, the market value of materials produced, and employment in the aggregate industry as evidence of the industry's economic significance. Another aspect often described is to highlight how the industry's products are used downstream by other businesses in the state, and how the downstream businesses would suffer without them. Neither approach provides a complete picture of the real economic significance of the aggregate industry because it cannot establish an inescapable dependency on local aggregates. To remedy the inadequacy of traditional studies, the present study includes not only the conventional approach, but also the aggregate industry's measurable economic contributions by way of jobs and income in the industry itself, upstream businesses that provide goods and services to the aggregate industry, and further upstream, how the aggregate industry induces jobs and income in businesses and social services essential for the functioning of the communities in which employees live. If the aggregate industry in the state reduces production, the consequences for upstream businesses are inescapable. Unlike the effects on downstream businesses, the upstream effects are measurable and causally connected to the aggregate industry. With the chain of jobs dependent on the aggregate industry come the jobs and income they generate at each subsequent level. These direct, indirect, and induced effects, called Type II multipliers, are measured by the U.S. Bureau of Economic Analysis. The inclusion of measurable direct, indirect, and induced economic effects, in addition to the conventional study approach, provides for the first time a complete measure of the aggregate industry's economic significance for the state of Illinois.

INTRODUCTION

Construction aggregates, aggregates for short, are minerals used in the building of roads, highways, airports and runways, offices, schools, shopping malls, hospitals, homes, storm and sewage systems, railroads, waterways, and many other facilities essential for modern-day societies. Aggregates include primarily crushed stone (mostly limestone and dolomite in Illinois) and construction sand and gravel. Other naturally occurring materials, such as silica sands (also called industrial sands), gypsum, and clays, are used to manufacture cement and lime used in construction. Products using cement, gypsum, and silica sand, such as drywall, pipes, ceramics, and glass, are also used in construction. These are very basic materials, many of which have been used by humankind for thousands of years, although the form in which they are used may have changed as technologies have developed to improve the products and construction techniques. Despite these changes, they remain essential to the construction industry because alternative materials have not been found that would be affordable enough to allow us to do without them. In fact, with a growing population and a prospering economy, the demand for these minerals and materials has steadily grown.

Illinois produces all the minerals listed above. This study focuses on crushed stone and construction sand and gravel as the dominant materials both by volume and by their dollar value. Silica sands have traditionally been used in glassmaking and foundry applications. In recent years, a new market has opened up for specialty silica sands in the production of oil and natural gas. Known as "fracking sand" or "frac sand," these sands of high-purity silica, rounded shape, and high strength are used to fracture oil- and gas-bearing geologic formations under high hydraulic pressure and to facilitate the flow of these fuels to the producing wells.

Modern civilization would be unthinkable without the aggregates. However, there is growing resistance to the mining of aggregates, in part because of a concern for the environment, but also because of the desire not to live in close proximity to mining sites. Economic considerations require that aggregates be used close to their places of mining because transportation costs can easily double the price of aggregates in the 20- to 50-mile (32- to 81-kilometer) range from the mines (Bhagwat 2000, 2015). Most aggregates are transported by trucks because geology dictates the location of their occurrence and because other cheaper modes of transportation, such as barges or trains, are often not accessible nearby. As a result of these pressures, aggregate mining has been moving away from urban centers to the outlying regions whenever suitable geologic reserves are available.

Illinois had about 150 producing stone quarries in 2012. However, in the Chicago metropolitan region, for example, two major limestone quarries account for about 20% of the state's production, whereas a large number of smaller quarries are located in the northwestern counties of the state, away from Metro Chicago yet close enough to be able to supply the growing suburban developments (Lasemi et al. 2010; Figure 1). The number of stone quarries in Illinois has declined over several decades (Mikulic 1989). Since 2000, some 50 more quarries have been idled. To keep up with the rising demand, the average production from the remaining facilities has increased over time. Supporting the geographic migration of stone quarries was the geology of northern Illinois, which has endowed the region with abundant, near-surface stone resources. In some cases, extraction of deeper stone deposits from underground mines became feasible, which helped prevent migration. Figure 2 depicts the locations of the approximately 115 producing sand and gravel pits in Illinois. Unlike the stone quarry locations, the sand and gravel pits are concentrated in or near the populated counties of northeastern Illinois. Although their number has declined over the decades, the glacial deposits of the area provide for sand and gravel resources there and along major rivers, such as the Illinois River, making it unavoidable for sand and gravel to be extracted closer to the populated northeast. The proximity of sand and gravel resources to human populations continues to give rise to resistance to their mining in some of the most rapidly urbanizing areas of the northeast. At the same time, the demand for and production of aggregates are affected by the state of the economy and the financial markets. Some of the major influencing factors are interest rates and the value of construction projects (Bhagwat 1989).

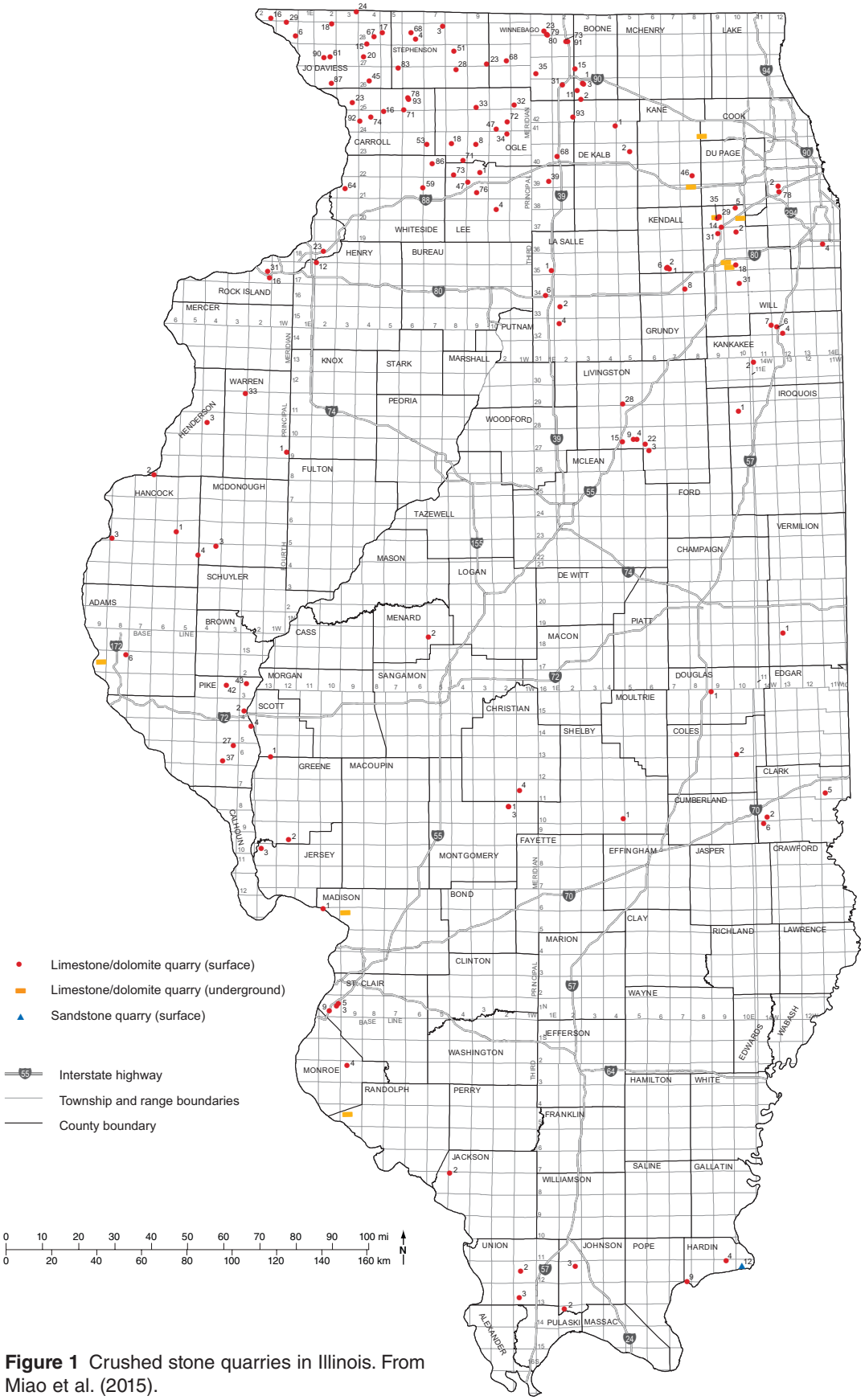

Figure 1 Crushed stone quarries in Illinois. From Miao et al. (2015).

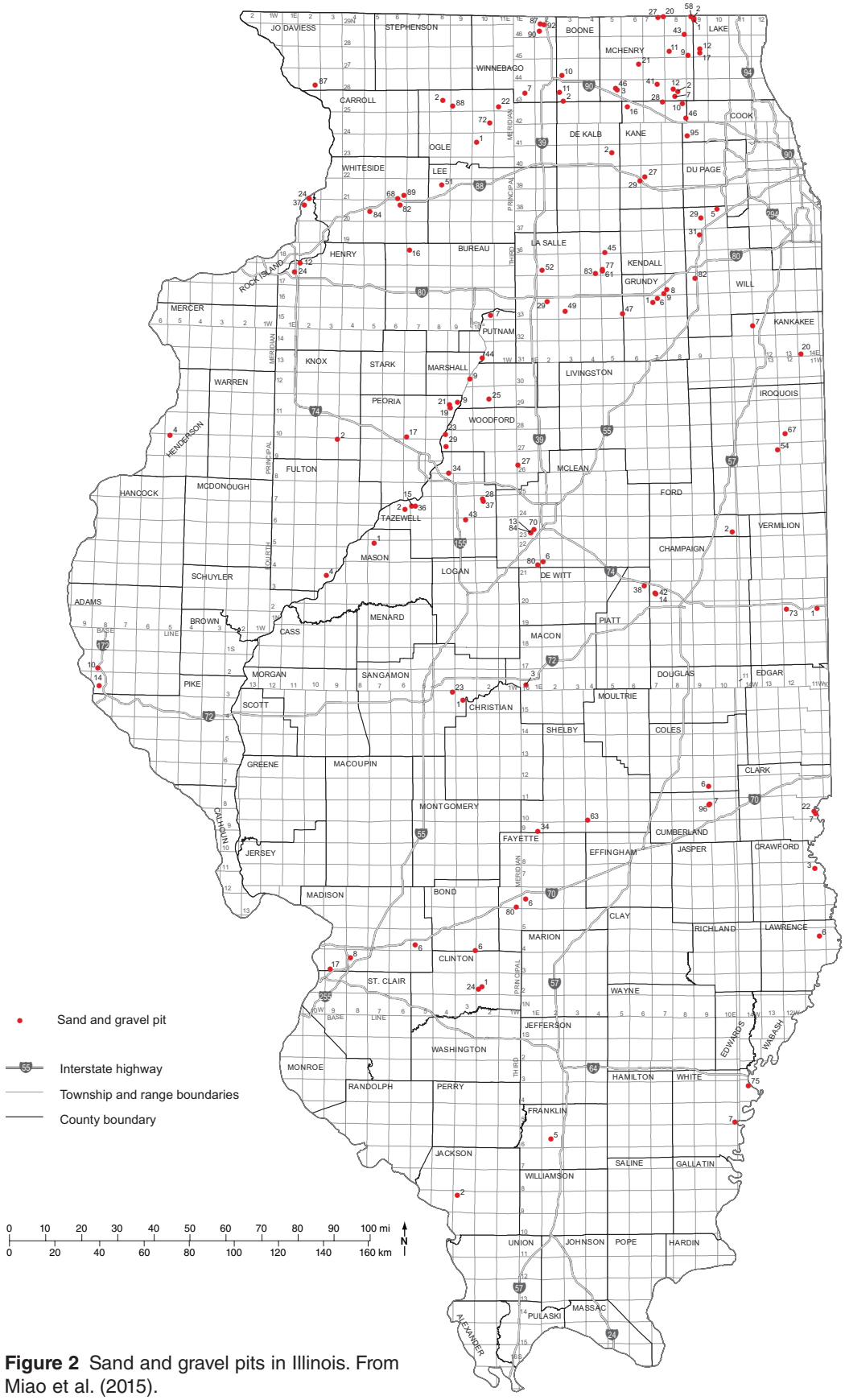

Figure 2 Sand and gravel pits in Illinois. From Miao et al. (2015).

Local demographic changes likewise influence not only the demand, but also the production in specific regions of the state. Figure 3 shows in blue the top 10 counties that gained population in the 1990–2010 period and in red the top 10 that lost the most population. The trend is clearly toward a population shift to the northeast surrounding the city of Chicago. The total population of Illinois grew by about 12% over the same period (U.S. Census data for 1990 and 2010; http://www.census.gov, http://www.census.gov/population/www/censusdata/cencounts/files/il190090.txt, http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF). The growing population concentration in the northeast could cause greater pressure to be exerted against the extraction of limestone and sand and gravel there. The issue is not simply the availability of resources, but also the protection of the environment and the provision of a comfortable lifestyle for the residents. A balance needs to be found between continued urban expansion, longer commutes, air and water quality, and family life. As the demographics of the state change, so must policies to accommodate the changes and reconcile them with social and environmental needs. As the pressure mounts to move surface production away from communities, underground extraction of aggregates can sometimes be cost effective as well as acceptable to citizens. Even though underground extraction usually costs more than surface extraction, the savings in transportation costs can make it economically feasible (Bhagwat et al. 2002).

In addition to citizen concerns about living in immediate proximity to mining operations, concerns have been raised by individuals and groups regarding the acreage affected by pits and quarries. Stone quarries and sand and gravel pits usually affect small areas and lend themselves more readily to postmining reclamation and use than areas affected by coal surface mines. Many of the former sites of stone and sand and gravel mining now hold water and serve as recreational lakes or preferred locations for housing and other construction. Perceptions and preferences do differ, however, on the timing of such a transformation,

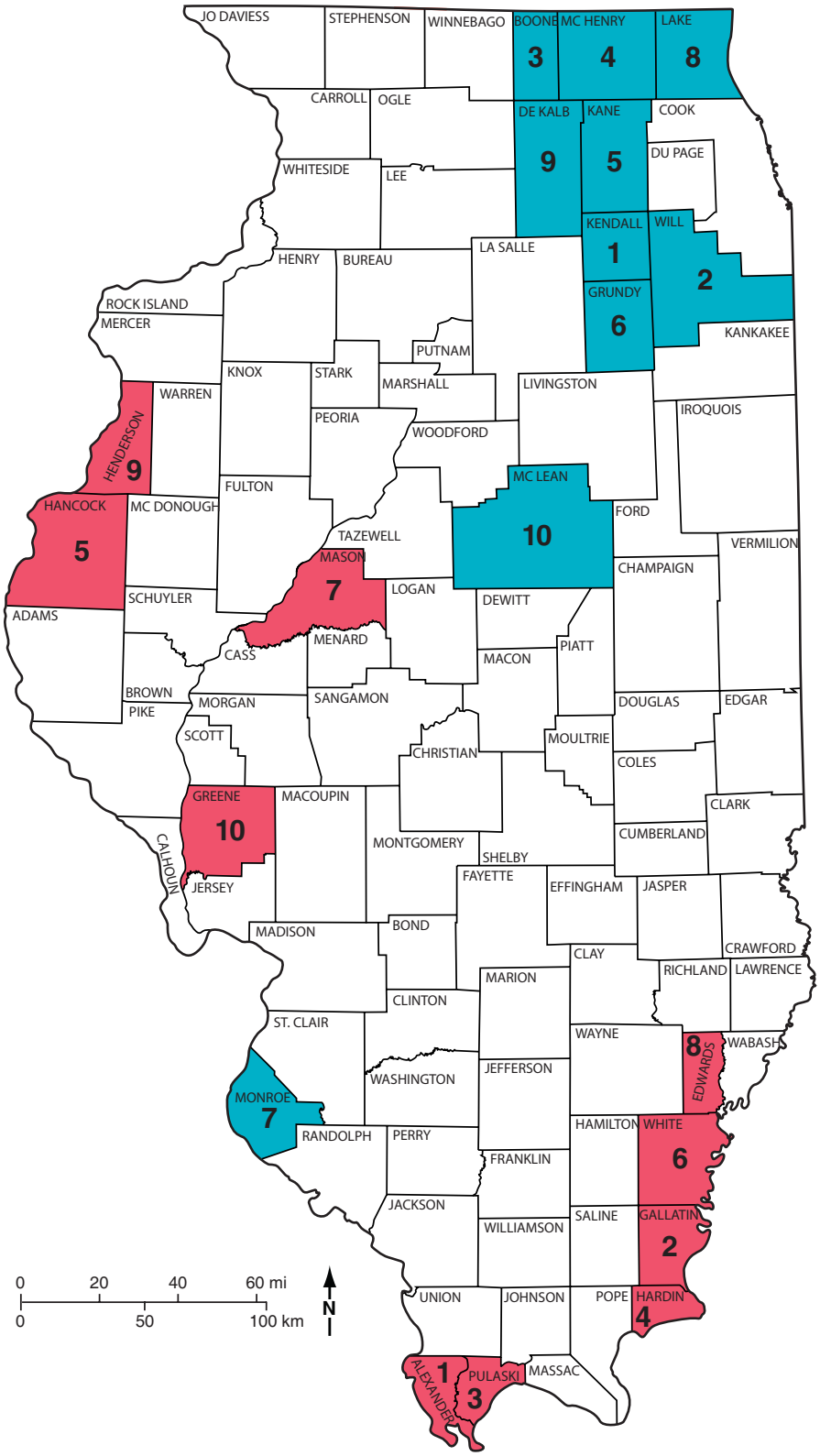

Figure 3 Changes in county populations in Illinois. Gains are shown in blue and losses in red. Data from the U.S. Census for 1990 and 2010 (http://www.census.gov).

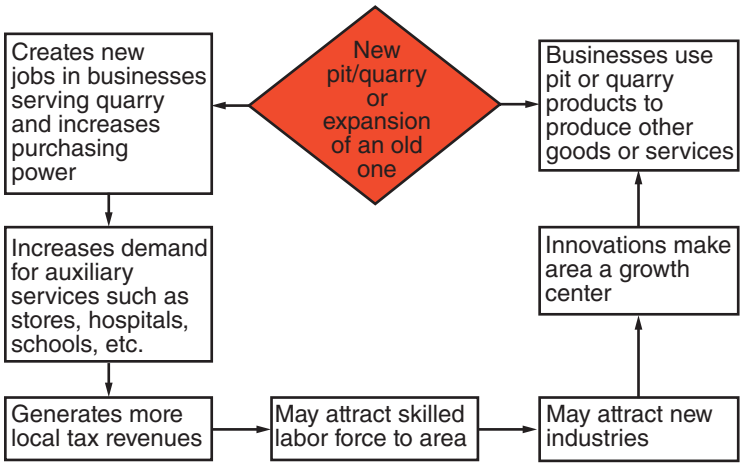

Figure 4 How economic multipliers work.

resulting in disputes and court litigation. As a result, coordination of mining and land-use planning has acquired urgency, especially in the northern regions of the state of Illinois. Along with new uses for naturally mined minerals, new concerns have emerged that deserve attention, as in the case of the frac sands (sands used in the hydraulic fracturing of rock formations to enhance the production of oil and gas) because of an observed correlation between increased oil and gas production and earthquakes.

On the positive side, the aggregate industry plays an important role in the local as well as the state economy. The most obvious benefits are the jobs directly created in the extraction of minerals. Additional economic benefits accrue as a consequence of the location of the industry. Societal decision making must weigh the sum total of benefits against the costs to the society. This study is intended to highlight the economic role of the aggregate industry in Illinois through all its direct and indirect significance to the state.

STUDY OBJECTIVES

The non-fuel minerals industry in general and the aggregates in particular are of fundamental economic significance to Illinois. At the same time, there are equally important environmental and social concerns regarding their conservation, extraction, and use. It is therefore critical to provide insight into the economic role the industry plays in the state. The objectives of the study include an overview of the economic value of aggregates, the industries that provide goods and services to the aggregate industry, the industries that use the aggregates, and the weight these carry in the overall economy of the state of Illinois. At each stage in the mining, processing, and utilization of the aggregates, more value is added to the economy, more jobs are created, and more revenue is generated to the governments at all levels to fulfill their obligations to the citizens in education, health, safety, and economic prosperity.

METHODOLOGY

This study of the role of mineral aggregates in the economy of Illinois is based on several decades of data. Even though some of the data are incomplete, the great value of what is available is recognized and utilized in this study. For example, some commercial operators and most seasonal private operators do not report production or employment figures. Small private sand and gravel operations as side businesses by landowners, for example, generally require no permits and remain unreported. Despite some of the problems with the available data, valuable trends are discernable and insightful observations are possible regarding the role of the industry in the economy of Illinois. This study highlights, in a manner plausible for the average reader, how the aggregate industry touches most sectors of the economy and quantifies its impact where possible.

The primary benefit of the growth of a business or industry is that it creates jobs. The payroll of the industry is a direct economic benefit. Beyond these direct benefits, goods and services are purchased from providers in the region, which helps create more jobs and more wealth. These secondary or indirect benefits, along with the primary benefits, contribute value to the economy through consumption of food, clothing, appliances, cars, and houses. In addition, services are required, such as schools, hospitals, police, firefighters, and many others, to maintain the infrastructure. All these activities create jobs and further contribute to the economy. The activity may result in attracting a skilled labor force and new businesses to the area and promoting innovations. It may also attract businesses that use as input products delivered by the aggregate industry. These benefits are tertiary or induced. Together, the direct, indirect, and induced contributions to the economy are called multipliers (Figure 4).

The national input–output (I-O) data provide detailed accounts of the direct, indirect, and induced effects on the gross economic product, employment, and value added (http://bea.gov/industry/io_annual.htm). These data sets are

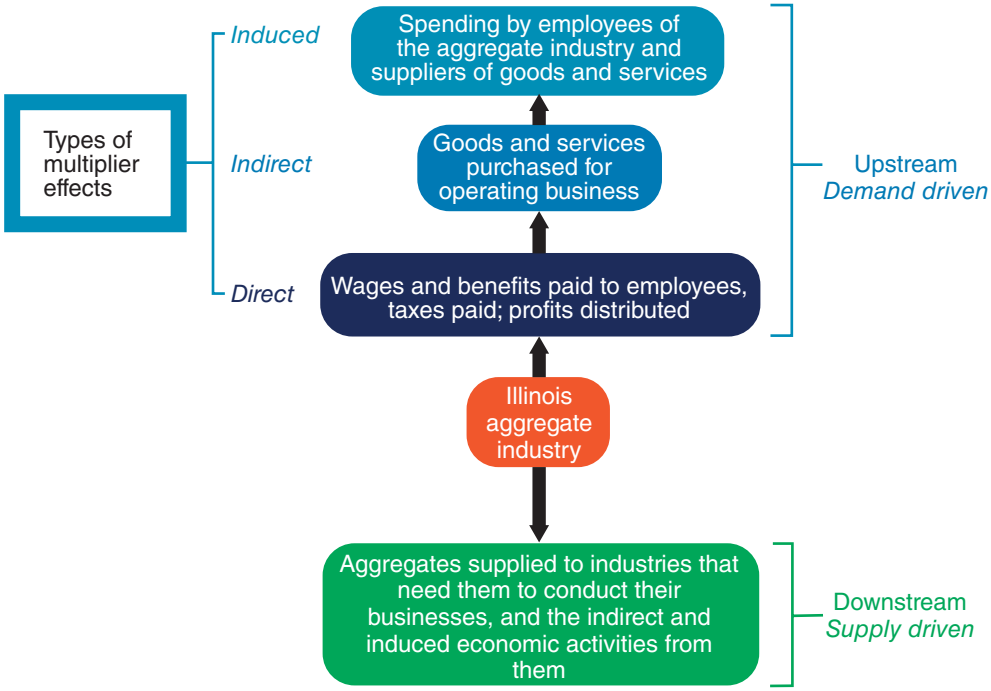

Figure 5 Upstream and downstream multiplier effects.

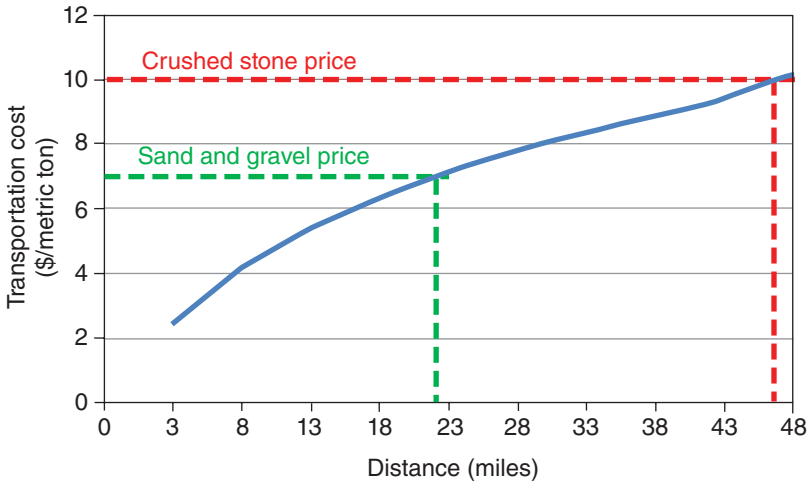

Figure 6 Simulated costs of aggregate transportation in 2014 (from Bhagwat 2015). For any distance (*x*-axis), add the transportation cost shown on the *y*-axis to the original aggregate cost (cost at the extraction site) to get the total cost per ton for the commodity. For example, at 22 miles (35 kilometers), the transportation cost is $7/ton. The total cost of sand and gravel aggregate will therefore be the cost of aggregate at the pit (currently averaging about $7/ton) plus a $7/ton transportation cost. Thus, sand and gravel aggregate will cost $14/ton at 22 miles (35 kilometers) from the source. Crushed stone costs more, about $10/ton. Thus, for crushed stone aggregate, the total cost will be $20/ton about 46 miles (74 kilometers) from the source.

used to assess the multiplier effects of the Illinois aggregate industry. Such multipliers are also called "demand-driven multipliers" or "upstream multipliers." On the downstream side of the aggregate industry are those industries and businesses that use the aggregates to produce other goods, objects, and services (Figure 5).

The existence of the downstream business activity is not exclusively tied to the Illinois aggregate industry because it can be argued that in the absence of the Illinois aggregates, the downstream industries could procure the required aggregates from somewhere else. In reality, however, such alternative sources have additional costs and may not always be feasible to obtain. The main additional cost is the transportation cost. Aggregates are relatively low priced but have to be trucked to the point of use. The cost of transportation by truck was estimated in a separate study using simulation as well as projection of previously reported costs using the Consumer and Producer Price Indexes (CPI and PPI; Bhagwat 2015). As Figure 6 indicates, the cost of truck transportation can double the consumer bill at 20 to 50 miles (32 to 81 kilometers) distance from the point of extraction. For example, sand and gravel are currently valued at about $7 per metric ton at the pit. Transporting it 22 miles (35 kilometers) to the point of

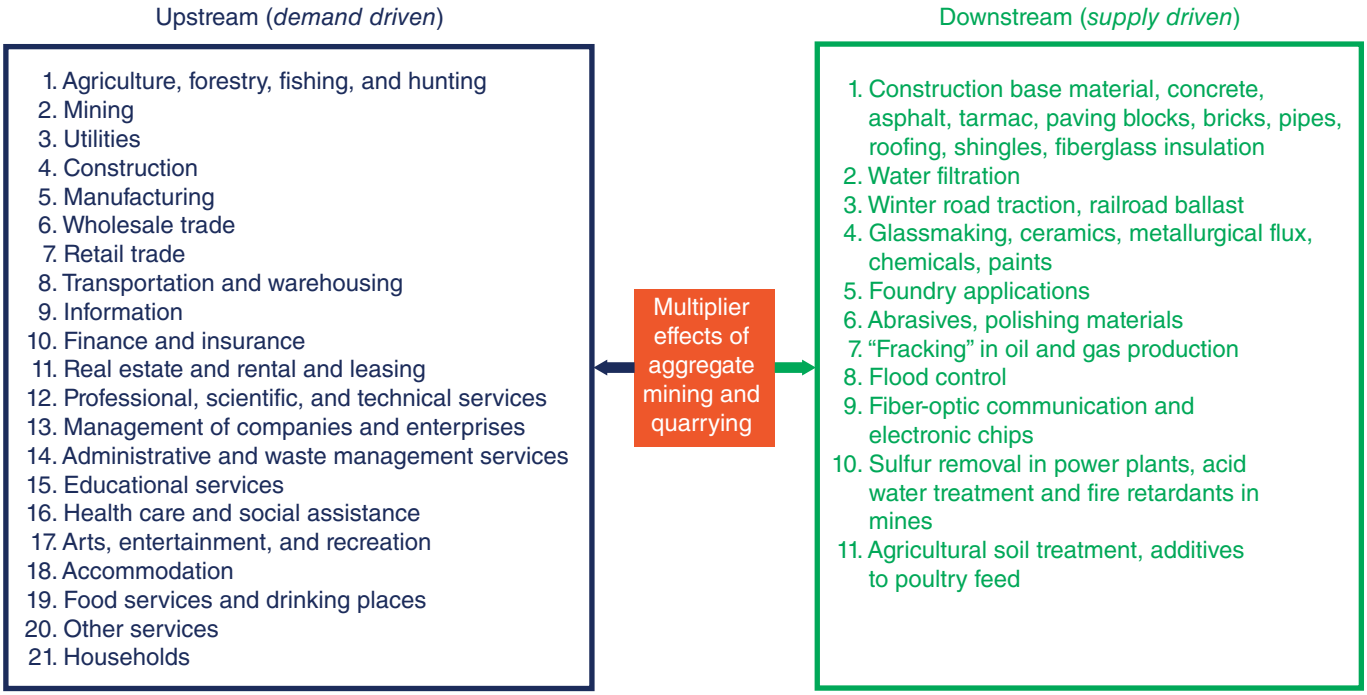

Figure 7 Industries doing business with the aggregate industry upstream and downstream.

its consumption costs an additional $7. The consumer thus pays $14 for one ton. Likewise, crushed stone is priced about $10 per metric ton at the quarry, and transportation by truck would add $10 more at a distance of about 46 miles (74 kilometers), thereby doubling the cost to the consumer. Considering that up to 10% of construction project costs are the costs of aggregates delivered to project sites (Bhagwat 1991), it is critical to keep transportation costs as low as possible.

Possible alternatives to truck transport exist where river barges or train connections are available. However, unlike trucking, barges and trains usually involve multiple modes of transportation in which trucks remain an essential mode. Multimodal transportation involving transloading also increases costs and imposes a limit on how far aggregates can be transported economically. As a result of the geographic limitations on how far away from the source of extraction the aggregates can economically compete in the marketplace, it is evident that many downstream buyers of Illinois aggregates can be considered dependent on them even though this dependency cannot be easily expressed in numbers in ways that upstream effects can be. In short, take away the supply of Illinois aggregates and we may change the entire composition of the economy, not only in Illinois but also in surrounding states and possibly in the entire nation. This study, therefore, walks you through the economy as aggregates move from pits and quarries to other uses in order to illustrate qualitatively how the supply-driven multiplier or the downstream multiplier works.

Figure 7 depicts the types of industries and businesses connected to the aggregate industry upstream and downstream, that is, industries and businesses that sell goods and services to the aggregate industry and those that buy the aggregates themselves. The lists may not be exhaustive because the ripple effects continue throughout the economy but remain unquantified. As indicated in Figure 7, even the documented effects on either side of the aggregate industry cover a wide swath of the economy, as is evident from the I-O accounts by the U.S. Bureau of Economic Analysis (BEA) referenced later.

THE AGGREGATE INDUSTRY OF ILLINOIS*

Illinois construction aggregate production—stone, and sand and gravel—has shown some interesting ups and downs over the past decades, primarily related to how the overall economy was doing at the time (Figure 8). A distinct decline in production can be seen during the economic recessions around 1980, in the early 1990s, and after 2008. The economic crisis since 2008 has affected aggregate production the most, with stone production down from nearly 80 million metric tons to about 45 million metric tons. In the years prior to 2008, stone production generally trended upward despite the longer recovery period after the 1980s recession. This has not been the case with sand and gravel production, which in 1971 reached its highest production in recent decades. The most recent decline in sand and gravel production appears to have set in almost 4 years before the 2008 recession even though the construction industry began the slowdown in 2008. It is possible that the decline from 2004 to 2008 may be more consistent with the past

*Production and value data from http://www.usgs.gov/energy_minerals/ (data courtesy of the U.S. Geological Survey).

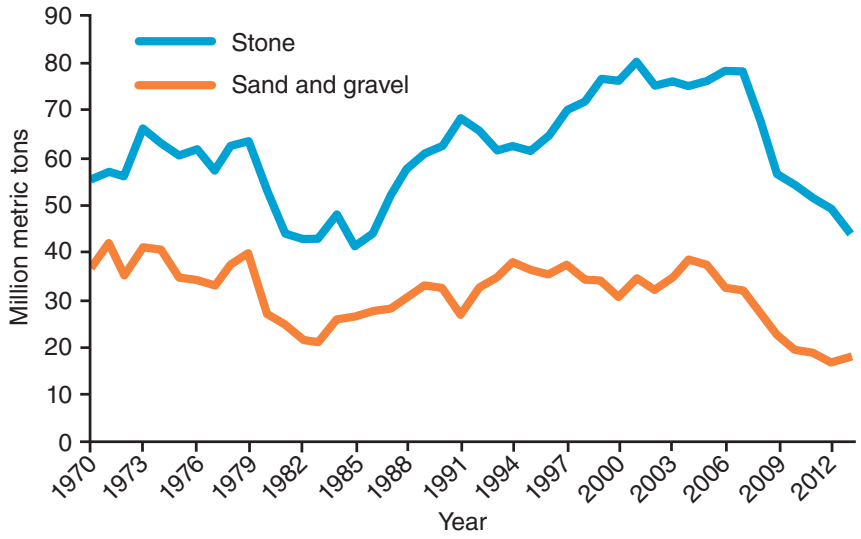

Figure 8 Production of stone and sand and gravel in Illinois. From U.S. Geological Survey Minerals Year Book (http://minerals.usgs.gov/minerals/pubs/myb.html), courtesy of the U.S. Geological Survey.

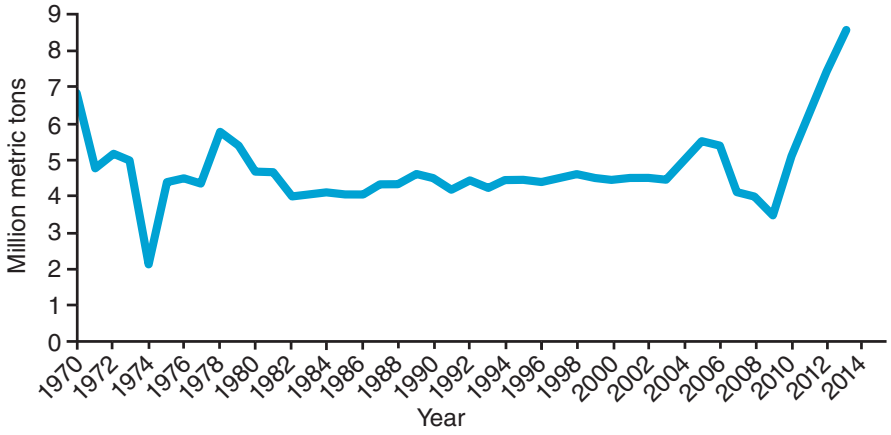

Figure 9 Production of industrial sand in Illinois. From U.S. Geological Survey Minerals Year Book (http://minerals.usgs.gov/minerals/pubs/myb.html), courtesy of the U.S. Geological Survey.

fluctuations in production and may have little to do with the crisis that followed that period.

Industrial sand traditionally has been used in the manufacture of glass and in foundries. In the past 6 years, specialty industrial sand has found a strong market in the oil and gas industry to fracture oil- and gas-containing geologic formations by pumping sand, water, and special chemicals under pressure to dramatically increase production (Figure 9).

Historically, clays played an important role in the aggregate industry. However, production began to decline after 1974 and reporting ceased after 2005. Portland cement, which is manufactured from naturally mined products and is used in the construction industry, displayed a downturn similar to stone production (Figure 10).

The decline in production since 2008 was in response to declining demand, and this trend helped to maintain profitable price levels. Figure 11 illustrates the steady price increases for stone as well as sand and gravel since 1970.

An even more dramatic price increase is displayed for silica sands (Figure 12) as a result of market growth in the oil and gas sector. Industrial sand prices rose from about $20 to more than $60 per metric ton in the 6 years since 2008. The nationwide consumption pattern for silica sands (Figure 13) shows the rapid increase in demand for fracking, now accounting for about two-thirds of the total demand and rising.

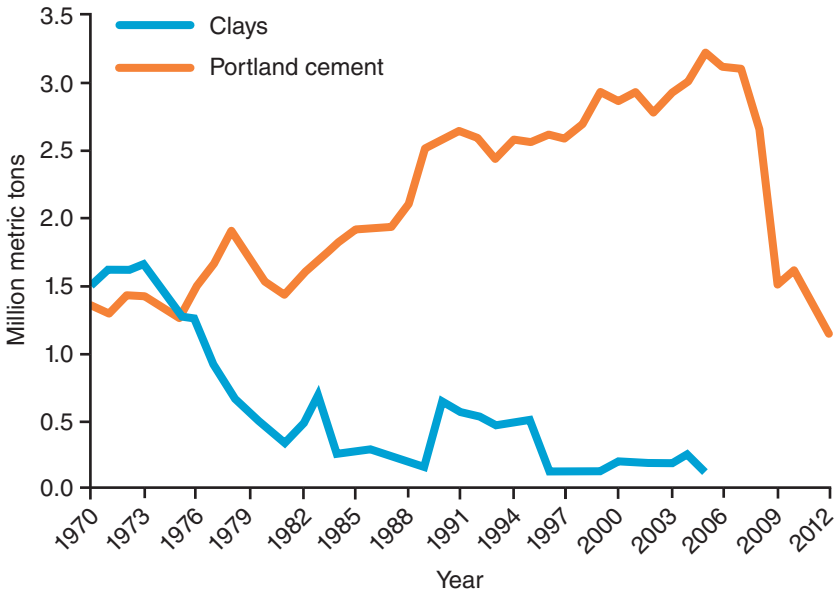

Figure 10 Production of clays and manufacture of portland cement in Illinois. From U.S. Geological Survey Minerals Year Book (http://minerals.usgs.gov/minerals/pubs/myb.html), courtesy of the U.S. Geological Survey.

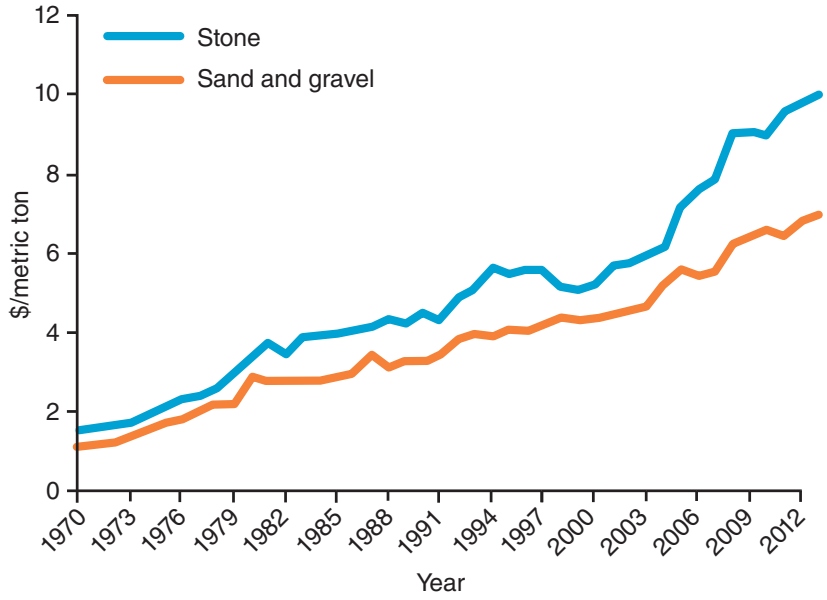

Figure 11 Prices of construction aggregates in Illinois. From U.S. Geological Survey Minerals Year Book (http://minerals.usgs.gov/minerals/pubs/myb.html), courtesy of the U.S. Geological Survey.

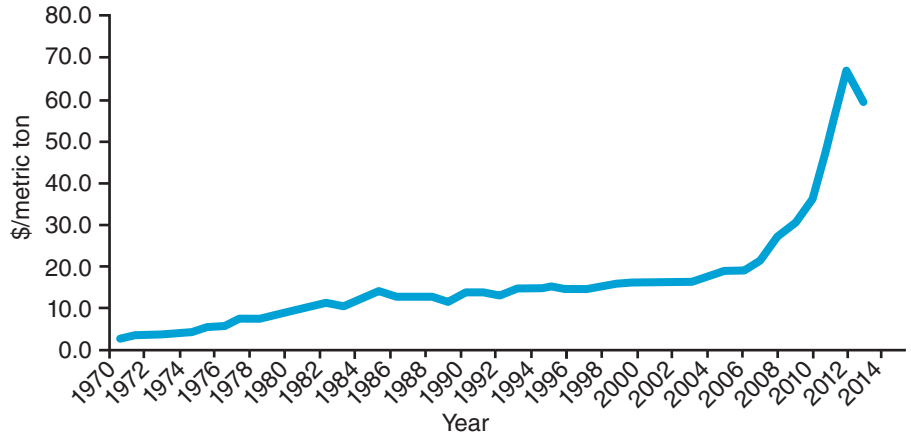

Figure 12 Price of industrial sand in Illinois. From U.S. Geological Survey Minerals Year Book (http://minerals.usgs.gov/minerals/pubs/myb.html), courtesy of the U.S. Geological Survey.

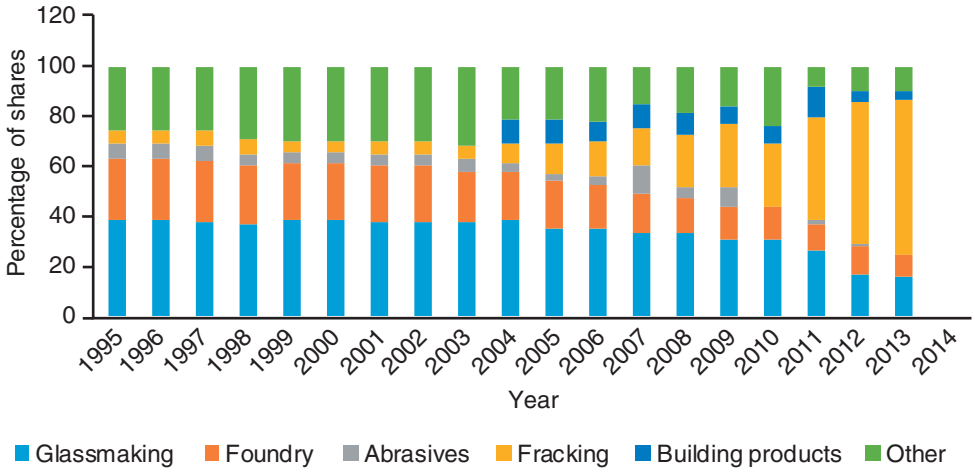

Figure 13 Uses of industrial sand in the United States. From U.S. Geological Survey Minerals Year Book (http://minerals.usgs.gov/minerals/pubs/myb.html), courtesy of the U.S. Geological Survey.

As a result of the 2008 economic crisis, the total value of industrial minerals produced in Illinois, which had reached $1.2 billion in 2006–2007, declined substantially after the 2008 economic crisis. The concurrent onset of a boom in demand for fracking sand raised the total value once again to $1.1 billion in 2013, with industrial sand alone leading with $0.5 billion (Figure 14).

The future of the aggregate industry is equally dependent on how the construction industry fares. Figure 15 illustrates that construction contributed more than $30 billion to the state's gross domestic product (GDP) in 2008 and that its share of GDP approached 5% in 2004 before residential construction began to decline. Since 2010, in part because of stimulus by the U.S. government, the value contributed by the construction industry and its share in the state's economy stabilized and has begun an upward trend.

Federal spending on construction mostly benefits infrastructure projects. Equally important is the private construction sector, which contributed about 38% to the total value of the Illinois construction sector in 2005. A recovery has been evident since 2009 (Figure 16). The higher than average unemployment rate in Illinois has been a major contributor to the decline and slow recovery of the private construction market as demand for housing has slowed. With the reduction in unemployment and continued low mortgage interest rates, the prospects for a demand recovery for construction aggregates in the next 5 years appear to be optimistic. With the support of a

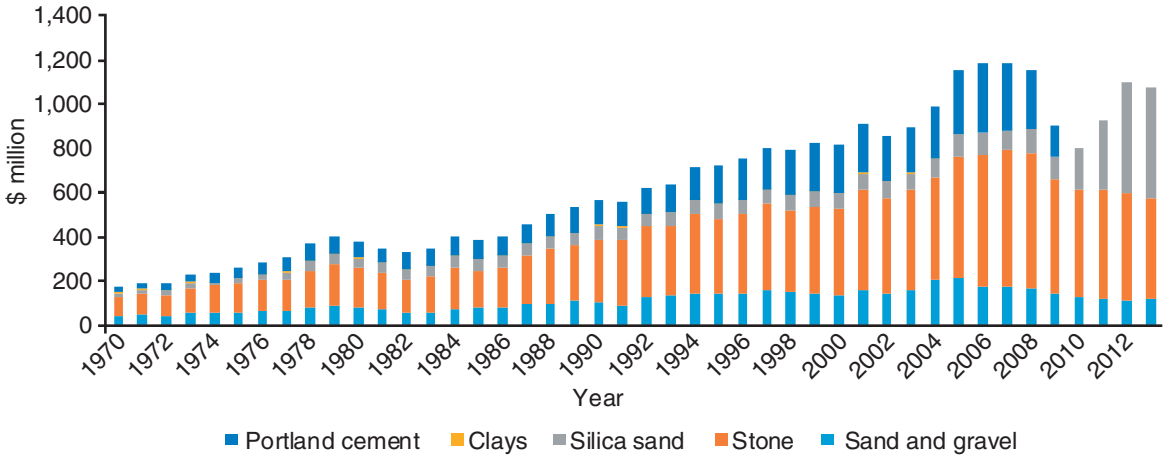

Figure 14 Total value of aggregate production in Illinois. From U.S. Geological Survey Minerals Year Book (http://minerals.usgs.gov/minerals/pubs/myb.html), courtesy of the U.S. Geological Survey.

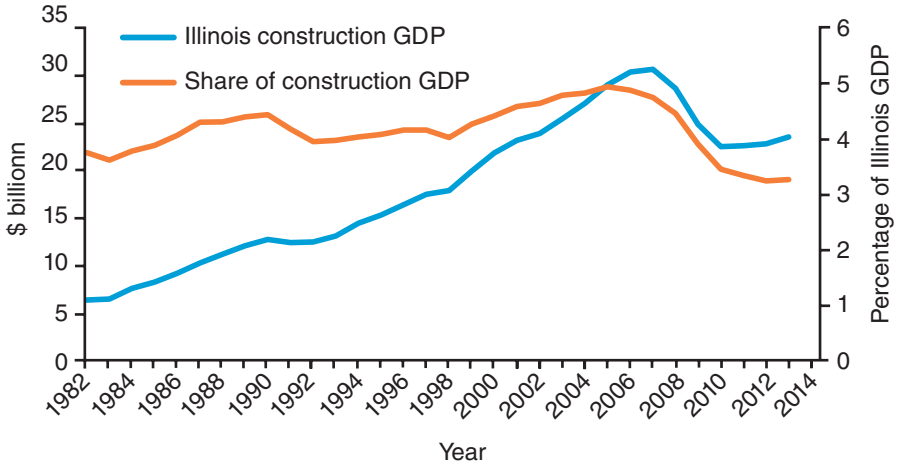

Figure 15 The construction industry in the Illinois economy. From U.S. Bureau of Economic Analysis (http://www.bea.gov/itable/index.cfm).

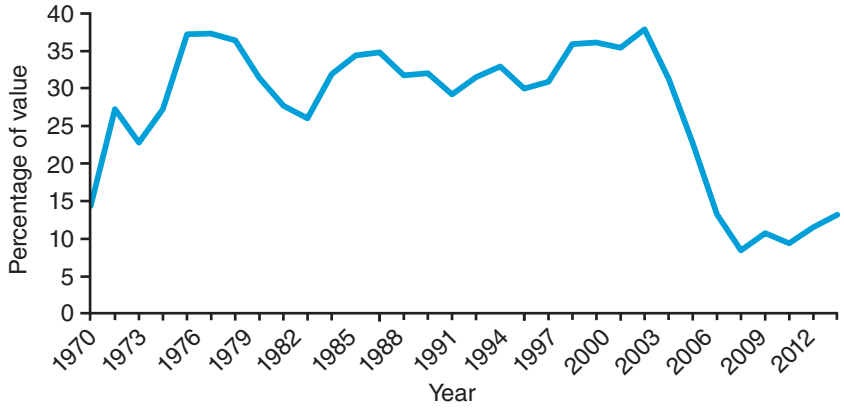

Figure 16 Share of private housing in the value of the Illinois construction industry. From U.S. Census Bureau (https://www.census.gov/construction/c30/historical_data.html).

strong demand for industrial sand in the oil and gas market and a recovery in the construction market, it is conceivable we may see the total value of Illinois aggregates reach $1.5 billion in the next 5 years. However, state and federal funding of the infrastructure programs remains a source of uncertainty.

Downstream or Supply-Driven Effects of the Illinois Aggregate Industry

As depicted in Figure 7, the products of the aggregate industry are used in a diverse range of industries, many of which are parts of or closely associated with the construction industry. These are products such as glass windows, bricks, pavement blocks, pipes, fiber-optic cables, fiberglass insulation, and roofing shingles. Outside the wider construction field, aggregates are also used in agriculture for soil conditioning and poultry feed. Limestone is used in coal mining as a fire retardant and as a treatment for acid water, and in coal-burning power plants it is used to remove sulfur from flue gases. Limestone is also used in papermaking. In oil and gas extraction, specialty sands are used in the fracturing of reservoir rock. Foundries use sand to make molds, and water and sewage treatment plants use sand and gravel. Table 1 provides an overview of selected major economic sectors that use aggregates or products made from them; also listed are the number of people employed in these sectors and their payrolls.

In 2012, the nonmetallic mining and quarrying sector in Illinois, which primarily consists of aggregates and the supporting businesses, employed 4,903 persons, 2,236 of whom were in support activities related to mining (Table 1). For every person employed in the extraction business, another 0.8 person found a job in a business that served the extraction business. The payroll in the mining and quarrying sector alone amounted to $165 million. These are direct economic contributions. The annual payroll for support services amounted to $120 million, which counts as indirect contributions to the economy. The direct benefits are discussed in detail quantitatively in the section on upstream multipliers.

The total number of people employed in 2012 in the selected downstream sectors outside the aggregate industry and its supporting businesses listed in Table 1 was 227,130, or 46 times higher than in the industry itself. The payroll in the listed sectors that consume the aggregates amounted to $14.2 billion, or 80 times the size of the payroll of the aggregate industry and its supporting businesses. Columns 6 and 7 of Table 1 show, respectively, the ratios of employment and payroll of the aggregate industry to the other sectors. Columns 8 and 9 show the employment and payroll ratios of sectors downstream from employment and payroll in the aggregate industry and its supporting businesses. The construction industry is predominant in that it employs 36.8 persons for each person employed by the aggregate industry and its supporting businesses, and the payroll of the construction industry is 40.8 times larger.

Substantial revenues are generated for the state and local governments as a result of the payrolls of the downstream sectors. It is instructive to consider the state income tax generated even if after deductions only half of the $14.2 billion payroll were taxable in Illinois. In recent years, the state income tax rate has been a flat 5% of taxable income. Beginning January 2015, it was reduced to 3.75%. Each of these sectors in turn exerts both upstream and downstream economic multipliers of its own, making further contributions to the state's economy.

As explained earlier, downstream economic connections cannot be strictly interpreted as causative. Consequently, the U.S. BEA does not calculate or publish downstream or supply-driven economic multipliers. Yet the cost of transporting aggregates is high in relation to the Free On Board (F.O.B.) price of aggregates, thus restricting the geographic radius within which buyers of aggregates actually tend to make their purchases. Consumers located near the borders with adjoining states or those with access to cheaper modes of transportation, such as a direct connection to barge transportation or a dedicated rail connection, may be able to resort to alternative sources of aggregates from other states. In Chicago, for example, the access to Lake Michigan and the major rivers in Illinois, and its proximity to Indiana offer consumers the opportunity to explore aggregate purchases from outside Illinois. No data are available to ascertain whether such traffic takes place and how much occurs. On the other hand, any possible reduction in the cost of transportation could work both ways and open up potential markets for Illinois aggregates outside Illinois as well. Past production data indicate a steadily rising trend in Illinois production, tracking the rising demand in the state and possibly outside Illinois. The Illinois aggregate industry thus plays a significant role in the viability of downstream industries.

Upstream or Demand-Driven Effects of the Illinois Aggregate Industry

Unlike the downstream effects, a causal relationship exists between the aggregate industry in Illinois and its economic effects on the state's GDP as well as the number of jobs dependent on the aggregate industry. To capture the causal relationships quantitatively and use them for analytical and policy decisions, the BEA within the U.S. Department of Commerce maintains comprehensive I-O data on the U.S. economy. The concept behind the I-O approach, first expounded by Wassily Leontief in the 1930s and 1940s, is the idea that each product or service requires the "consumption" of other products and services up and down the economic chain. A change in any one of the inputs—cost, quantity, quality, and so forth—has an effect throughout the economy. The establishment of such I-O tables requires a detailed classification of products and services, as well as the identification of branches of the economy in which they are produced and consumed. Furthermore, individual establishments associated with the production and consumption of the goods and services need to be identified. Details of how this is done are available in *Concepts and Methods of U.S. Input–Output Accounts*, published by the BEA in 2006 and updated in 2009 (Horowitz and Planting 2006/2009).

Table 1 Employment and payroll in Illinois for the aggregate industry and connected industries (2012)[1]

Sector	No. of firms	No. of establishments	Employment	Annual payroll ($1,000)	Employment ratio	Payroll ratio	Ratio mining + supporting activities: others	
							Employment	Payroll
Nonmetallic minerals mining and quarrying	111	184	2,667	165,088	1.0	1.0		
Support activities for mining	193	194	2,236	120,132	0.8	0.7		
Construction	27,895	28,087	180,468	11,646,515	67.7	70.5	36.81	40.83
Paper manufacturing	211	251	16,861	898,235	6.3	5.4	3.44	3.15
Nonmetallic mineral product manufacturing	453	596	11,727	653,395	4.4	4.0	2.39	2.29
Foundries	109	112	7,190	326,488	2.7	2.0	1.47	1.14
Oil and gas extraction	159	160	1,006	60,426	0.38	0.364	0.21	0.22
Bituminous coal underground coal mining	10	11	2,406	183,890	0.9	1.11	0.49	0.65
Water, sewage, and other systems	73	117	1,969	107,449	0.74	0.65	0.40	0.38
Asphalt paving, roofing, and saturated material manufacturing	45	54	686	46,506	0.26	0.28	0.14	0.16
Paint, coating, and adhesive manufacturing	98	112	4,817	278,819	1.81	1.69	0.98	0.98

[1]Data source: U.S. Census Bureau (http://www2.census.gov/econ/susb/data/2011/us_state_6digitnaics_2011.txt, accessed June 27, 2016).

Using the I-O tables, the BEA calculates the effects of growth or decline in one industry on gross output, value added, earnings, and employment in industries that supply goods and services to the industry under consideration. This effect is called the upstream or demand-driven multiplier effect. The multipliers are available at both the national and regional levels. In the present study, we are interested in the multipliers of the aggregate industry in Illinois. The Regional Input—Output Modeling System (RIMS) estimates two types of multipliers RIMS-I (Type I) and RIMS-II (Type II). The BEA manual (Bess and Ambargis 2011) describes the difference as follows:

> Type I multipliers account for the direct and indirect impacts based on how goods and services are supplied within a region. Type II multipliers not only account for these direct and indirect impacts, but they also account for induced impacts based on the purchases made by employees. (p. 7)

The direct, indirect, and induced impacts are explained earlier in the study (see Figure 5).

The BEA cautions about the use of these multipliers:

> RIMS II multipliers are created to estimate the total impacts resulting from incremental changes in final demand. Because the model is based on existing industry relationships, they are not very well suited to estimate the total contribution of an industry to a local economy. (p. 15)

The addition or elimination of the industry changes the entire structure of the economy. They are, however, useful indicators of the importance of changes in the industry for employment and earnings in the region. Following the BEA advice, this study presents all four of the multipliers of the aggregate industry to provide insight into the magnitude of its potential for the Illinois economy but focuses on earnings and employment effects.

The multipliers used here are Type II; that is, they show the direct, indirect, and induced effects of the aggregate industry. Table 2 presents the multipliers between the sand and gravel industry in the state and the rest of the economy. The multipliers for the stone industry are presented in Table 3.

Listed down the first column in Tables 2 and 3 are industry sectors that supply goods and services to the respective aggregate sector. In column 2 are the multipliers affecting the values of outputs in the sectors listed in column 1. Column 3 shows the multipliers for earnings in those sectors, and column 4 lists the multipliers for the employment effects. Column 5 lists the multipliers for value added to the economy by these sectors. The last number in each column represents the sum of all multipliers in the column. The direct multiplier effects on earnings and employment are listed at the bottom of columns 6 and 7.

To properly interpret the numbers in Tables 2 and 3, it is necessary to pay close attention to the footnotes that follow the tables (see pages 15 and 16). First, a basic observation about the Type II multipliers: They include the direct economic effects, which begin with the aggregate industry employing people to produce the aggregates. Thus, an employment multiplier of 2.0 implies that when the aggregate industry employs one person, it generates one additional job, resulting in the multiplier of 2.0.

With this in mind, we illustrate the multiplier effect for earnings, defined in footnote 3 as "the total dollar change in earnings of households employed by all industries within the state for each additional dollar of output delivered to the final demand," in this case, by the sand and gravel industry.

The total earnings multiplier at the bottom of column 3 in Table 2 is 0.6207. When 1 metric ton of sand and gravel is produced and sold in Illinois at its current value of $7, it contributes 0.6207 × $7 = $4.35 to household earnings in Illinois, including the households of individuals employed by the sand and gravel industry. The direct effect of wages paid in the sand and gravel sector is captured by the bottom number in column 6 of Table 2. This number is $2.4144. According to footnote 6, this means that each dollar paid out to employees of the sand and gravel industry adds $2.41 to all the households in the state, including the households of the employees themselves. In other words, the households outside the sand and gravel industry get $1.41. The examples here show that not only do the production and price of aggregates matter, but also the level of wages paid in the aggregate industry when it comes to the effect on earnings of all households in Illinois.

Identical calculations for the stone industry in Illinois based on Table 3 data show a total earnings multiplier of 0.596 (column 3, bottom number), which at the current price of crushed stone of $10 per metric ton translates into household incomes of 0.596 × $10 = $5.96 for each ton of stone sold. This includes wages paid to stone industry employees. Likewise, the direct earnings effect (column 6) is $2.4686. This means that for $1 in wages earned by an employee in the stone industry, an additional $1.47 of income is generated for other households in Illinois.

The other relevant use of multipliers pertains to employment. In column 4 of Table 2, the total employment multiplier for the sand and gravel industry is 12.2305. This represents the total change in the number of jobs in all industries within the state for each additional million dollars of sand and gravel sold (footnote 4). In 2013, about $123 million worth of sand and gravel was sold from Illinois pits. With the multiplier, this translates to 12.2305 × 123 = 1,504 jobs, including those in the pits. The direct employment multiplier (Table 2, bottom of column 7) is 2.8594. This represents the change in the number of jobs in all industries within the state for each additional job in the sand and gravel industry (footnote 7). Every job in the sand and gravel industry creates 1.86 additional jobs.

Table 2 RIMS II multipliers (2002/2010): Final demand multipliers for Illinois sand, gravel, clay, and ceramic and refractory minerals mining and quarrying (Type II)[1]

Sector	Output[2]	Earnings[3]	Employment[4]	Value added[5]	Direct-effect earning[6] (dollars)	Direct-effect employment[7] (no. of jobs)
Agriculture, forestry, fishing, and hunting	0.0040	0.0006	0.0157	0.0015		
Mining	1.0661	0.2732	4.5812	0.5363		
Utilities	0.0766	0.0151	0.1422	0.0454		
Construction	0.0079	0.0029	0.0583	0.0039		
Manufacturing	0.1772	0.0327	0.6503	0.0571		
Wholesale trade	0.0568	0.0178	0.2498	0.0384		
Retail trade	0.0596	0.0203	0.8005	0.0390		
Transportation and warehousing	0.0776	0.0236	0.5027	0.0378		
Information	0.0542	0.0118	0.1845	0.0294		
Finance and insurance	0.1516	0.0472	0.8257	0.0899		
Real estate and rental and leasing	0.1554	0.0143	0.5485	0.1111		
Professional, scientific, and technical services	0.1037	0.0462	0.6411	0.0693		
Management of companies and enterprises	0.0862	0.0345	0.3195	0.0535		
Administrative and waste management services	0.0425	0.0176	0.7659	0.0276		
Educational services	0.0098	0.0040	0.1234	0.0056		
Health care and social assistance	0.0708	0.0330	0.7359	0.0434		
Arts, entertainment, and recreation	0.0089	0.0032	0.1563	0.0055		
Accommodation	0.0064	0.0019	0.0578	0.0042		
Food services and drinking places	0.0280	0.0089	0.4806	0.0146		
Other services	0.0363	0.0111	0.2863	0.0185		
Households		0.0008	0.1043	0.0008		
Total	2.2796	0.6207	12.2305	1.2328	2.4144	2.8594

[1]The Type I multipliers account for the direct and indirect impacts based on the supply of goods and services in the region. The Type II multipliers account for these same direct and indirect impacts, and for induced impacts, which are associated with the purchases made by employees. Source: Regional Input–Output Modeling System (RIMS II), Regional Product Division, Bureau of Economic Analysis, U.S. Department of Commerce. 2002 U.S. benchmark input–output data and 2010 regional data.

[2]Each entry in column 2 represents the total **dollar change in output** that occurs **in all industries** within the state **for each additional dollar of output** delivered to final demand by the selected industry.

[3]Each entry in column 3 represents the total **dollar change in earnings of households employed by all industries** within the state **for each additional dollar of output** delivered to final demand by the selected industry.

[4]Each entry in column 4 represents the total **change in number of jobs** that occurs **in all industries** within the state **for each additional million dollars of output** delivered to final demand by the selected industry. Because the employment multipliers are based on regional data, the output delivered to final demand should be in regional year dollars.

[5]Each entry in column 5 represents the total **dollar change in value added** that occurs **in all industries** within the state **for each additional dollar of output** delivered to final demand by the selected industry.

[6]Each entry in column 6 represents the total **dollar change in earnings of households employed by all industries** within the state **for each additional dollar of earnings paid directly to households employed by the selected industry.**

[7]Each entry in column 7 represents the total **change in number of jobs in all industries** within the state **for each additional job in the selected industry.**

Table 3 RIMS II multipliers (2002/2010): Final demand multipliers for Illinois stone mining and quarrying (Type II)[1]

Sector	Output[2]	Earnings[3]	Employment[4]	Value added[5]	Direct-effect earnings[6] (dollars)	Direct-effect employment[7] (no. of jobs)
Agriculture, forestry, fishing, and hunting	0.0037	0.0005	0.0148	0.0014		
Mining	1.0796	0.2605	4.8561	0.5913		
Utilities	0.0647	0.0129	0.1211	0.0388		
Construction	0.0073	0.0027	0.0544	0.0037		
Manufacturing	0.1485	0.0272	0.5347	0.0482		
Wholesale trade	0.0517	0.0162	0.2275	0.0349		
Retail trade	0.0574	0.0195	0.7709	0.0376		
Transportation and warehousing	0.1126	0.0366	0.7829	0.0558		
Information	0.0515	0.0111	0.1747	0.0279		
Finance and insurance	0.1418	0.0439	0.7664	0.0839		
Real estate and rental and leasing	0.1491	0.0142	0.5245	0.1054		
Professional, scientific, and technical services	0.0895	0.0400	0.5573	0.0600		
Management of companies and enterprises	0.0821	0.0328	0.3043	0.0510		
Administrative and waste management services	0.0404	0.0171	0.7512	0.0265		
Educational services	0.0094	0.0038	0.1183	0.0054		
Health care and social assistance	0.0680	0.0318	0.7075	0.0417		
Arts, entertainment, and recreation	0.0085	0.0031	0.1482	0.0052		
Accommodation	0.0062	0.0019	0.0554	0.0040		
Food services and drinking places	0.0268	0.0085	0.4595	0.0139		
Other services	0.0357	0.0109	0.2785	0.0182		
Households		0.0008	0.1001	0.0008		
Total	2.2345	0.5960	12.3083	1.2556	2.4686	2.7347

[1]The Type I multipliers account for the direct and indirect impacts based on the supply of goods and services in the region. The Type II multipliers account for these same direct and indirect impacts, and for induced impacts, which are associated with the purchases made by employees. Source: Regional Input–Output Modeling System (RIMS II), Regional Product Division, Bureau of Economic Analysis, U.S. Department of Commerce. 2002 U.S. benchmark input–output data and 2010 regional data.

[2]Each entry in column 2 represents the total **dollar change in output** that occurs **in all industries** within the state **for each additional dollar of output** delivered to final demand by the selected industry.

[3]Each entry in column 3 represents the total **dollar change in earnings of households employed by all industries** within the state **for each additional dollar of output** delivered to final demand by the selected industry.

[4]Each entry in column 4 represents the total **change in number of jobs** that occurs **in all industries** within the state **for each additional million dollars of output** delivered to final demand by the selected industry. Because the employment multipliers are based on regional data, the output delivered to final demand should be in regional year dollars.

[5]Each entry in column 5 represents the total **dollar change in value added** that occurs **in all industries** within the state **for each additional dollar of output** delivered to final demand by the selected industry.

[6]Each entry in column 6 represents the total **dollar change in earnings of households employed by all industries** within the state **for each additional dollar of earnings paid directly to households employed by the selected industry.**

[7]Each entry in column 7 represents the total **change in number of jobs in all industries** within the state **for each additional job in the selected industry.**

Employment

$1 million worth of aggregates sold generates 12.2 to 12.3 jobs in Illinois, including those in the aggregate industry.

1 additional job in the aggregate industry generates an additional 1.74 to 1.86 jobs in the rest of Illinois.

Source: Fotolia.

Earnings

$1 worth of aggregates sold generates $0.60 to $0.62 in wages for all workers in Illinois, including those in the aggregate industry.

$1 in wages paid to workers in the aggregate industry generates an additional $1.41 to $1.47 in wages to workers in the rest of Illinois.

Figure 17 Upstream economic multipliers of the aggregate industry in Illinois.

In the Illinois stone industry, the employment multiplier is 12.3083 (Table 3, bottom of column 4). This means that $1 million worth of stone sold creates 12.3083 jobs in the state (footnote 4). In 2013, about $447 million worth of crushed stone was sold, resulting in 12.3083 × 447 = 5,502 jobs in the state, including those employed in stone extraction. The direct employment multiplier for the Illinois stone industry in column 7 of Table 3 is 2.7347. This signifies that for each job in the stone industry, an additional 1.74 jobs are created in Illinois (footnote 7).

The number of jobs created in and outside sand and gravel pits (1,504 in total) and stone quarries (5,502 in total) adds up to 7,006 jobs. The data in Table 1 show an employment figure of 2,667 in nonmetallic minerals mining and quarrying in Illinois in 2012. Employment numbers for 2013 are not available; however, the 2013 employment number could have been lower because of the lower production. In addition, the data in Table 1 are subject to some inaccuracies as a result of reporting problems. It can be concluded that approximately 4,339 jobs are directly the result of 2,667 jobs in the aggregate industry; that is, for every person employed in the aggregate industry, 1.63 additional jobs are supported in Illinois. Comparable numbers derived from the RIMS II multipliers above are 1.74 (stone) and 1.86 (sand and gravel). The data collection and cross-verification system of the BEA is highly elaborate and has been in place for decades. It would therefore be safe to conclude that the multiplier-based job estimates can be trusted.

As seen earlier, the earnings created in the rest of the Illinois economy for every $1 of wages paid in the aggregate industry amount to $1.41 (sand and gravel) and $1.47 (stone). Once again, a comparison with Table 1 data shows that the payroll of the nonmetallic mining and quarrying industry in Illinois is $165 million. The resultant payrolls in the rest of the Illinois economy would be about $240 million annually. The earnings and employment multiplier effects measured upstream from the Illinois aggregate industry are summarized in Figure 17.

Aggregate Mining and the Illinois Environment

The mining of aggregates mostly takes place in open pits and quarries. For reasons of transportation economics, but also for environmental reasons, mining locations are within relatively short distances from the locations of aggregate consumption. Ironically, the very objects built with the mined materials—homes, commercial and industrial buildings, roads, and highways—eventually approach the mining sites as cities grow and suburbs are developed. When this happens, the location of mines near human habitation becomes undesirable because of the truck traffic; the perceived or real problems of dust, noise, and vibrations; and the unsightliness of mining operations. Particularly in the densely populated northeastern counties of Illinois, this phenomenon has resulted in the closing down of quarries and pits over decades and the concentration of more production from fewer remaining operations (Mikulic 1989). These remaining operations mine from deeper deposits and are often bounded by housing right at their edges. Eventually, the deep and closely encircled pits and quarries will cease to operate, either because their reserves are exhausted or because public opinion does not permit continued operation. The interplay of economic necessity of mineral materials for continued and competitive growth on one hand, and environmental or aesthetic concerns on the other will ultimately decide the future of mining in many areas of the state. If most quarries and pits near human habitation are closed, where will the aggregates in the future come from and at what cost?

The increased use of recycled construction materials, especially from road surfaces, is a partial substitute for natural mined materials. Recycling is

environmentally desirable and often economically viable. However, high-quality recycled quantities are limited and are unlikely to completely replace mined materials.

One attempt to answer this dilemma in recent decades comes from the idea of mining crushed stone by underground methods similar to those used in coal mining. Several underground stone mines operate in Illinois, and the future may see many more of them as demand grows while at the same time mining sites become scarce because of urban development. It is estimated that currently about one-sixth ($100 million in value) of Illinois' aggregates come from underground mines. Stone is mined deep in the ground in operations invisible from the surface. Underground mining increases the cost of mining, in part because extraction rates decrease, but also because underground mining restricts the size of equipment used and requires added health and safety measures. An ISGS model economic study has indicated, however, that the cost increase is expected to be marginal and probably acceptable in the current market environment (Bhagwat et al. 2000). The limiting factors in underground stone extraction are geology and market price.

Some mitigating economic factors make both open pits or quarries and underground extraction attractive when one considers the postmining uses of land. For example, the large lakes created at the open pits and quarries offer excellent recreational and water sport sites. The land surrounding these lakes also offers desirable housing locations, thereby contributing to the enhancement of land values in the area. Likewise, in the Chicago area, open pits resulting from stone mining are used as overflow catchments for the storage of storm and sewer water before treatment and disposal. Water bodies also tend to attract birds. Some species stay in the area year round, whereas others are migratory. If properly managed, the same water bodies can serve as habitats for fish.

Another concept of postmining land use is to develop underground spaces for commercial and industrial uses. The real estate company Hunt Midwest has 6 million square feet of space underground in limestone formations near Kansas City, Kansas, where major manufacturers and warehouse businesses operate (http://www.huntmidwest.com/subtropolis/). Large underground spaces in stone deposits offer geologically stable environments. Their deep locations mean nearly constant year-round temperatures of 50 to 55 °F, which minimize the need for seasonal heating and cooling. If such locations are in the middle of industrial or commercial areas, they become ideal warehouse locations as well as manufacturing sites. The long-term revenue streams that could be generated from the underground use of space contribute to payment of some of the higher mining costs.

In the end, a need exists for a comprehensive study of the ways to optimally use the available resources of construction aggregates and arrive at a balanced solution because their economic significance for Illinois is crucial and vital. An important prerequisite to achieve this goal is to have complete knowledge of where the resources are, their quality, and how large they are. The only way to obtain this knowledge is to study the state's geology and create maps for the decision makers at all levels of society. Land-use decisions made in the absence of such knowledge entail the risk that potential resources could be made permanently inaccessible. An ISGS study has documented the economic payout of geologic mapping to the society (Bhagwat and Ipe 2000). An additional requirement in Illinois is the development of uniform guidelines for the extraction of minerals that balance the social, environmental, and economic needs in the long term. At present, land-use decisions are in the purview of local authorities. As a result, decisions are often influenced by short-term considerations and subjective factors while ignoring the society's long-term interests.

Finally, it must be recognized that active participation of the aggregate industry is essential if policies of the future are to be in the overall interest of Illinois. Industry participation in funding as well as execution of research to foster sustainable resource extraction can contribute to the development of an atmosphere of confidence among the individual and corporate citizens of Illinois.

SUMMARY

Every industry has an economic effect on several other industries because of the goods and services it purchases from them or sells to them. This is called the "multiplier effect." The former group of industries are "upstream," whereas the latter are "downstream" from the industry concerned. In this case, the industry concerned is the aggregate industry in Illinois. These economic effects are called multipliers because jobs are created or supported and incomes are generated. The effects are categorized as direct, indirect, and induced.

Only the upstream effects can be reliably considered as caused by the aggregate industry because without the Illinois aggregate industry as a customer, these specific business transactions would not take place. The direct effects are those within the aggregate industry itself, that is, the people it employs and the wages they earn. The indirect effects consist of employment and wages in businesses that supply goods and services to the aggregate industry, and the induced effects are those further upstream, such as in sectors that serve the suppliers and provide other services, such as schools, hospitals, housing, police, and fire protection. The BEA collects such data in detail, compiles them, and calculates the multiplier factors on regional and national levels for industries, and then makes them available to researchers and policy makers.

Although the BEA recognizes that multiplier effects exist downstream from industries as well, no multiplier factors are calculated because the causal connection between the buyer and seller cannot be established. For example, in the Illinois aggregate industries, it is indisputable that the construction industry in Illinois would not exist without the supply of aggregates, but the aggregates need not necessarily come from an Illinois source. In reality, it is evident that a majority of businesses in the state's construction industry purchase Illinois aggregates because it is the most economical source for them. Therefore, an economic multiplier does

exist downstream as well, even though it is not numerically determined.

To fully explain the economic multiplier effect of Illinois' aggregate industries—crushed stone, sand and gravel, and silica sands—this study uses the multipliers from the BEA to quantify and interpret the upstream employment and income effects. This study also provides elaborate data on the aggregate industries, as well as on industries that use the aggregates. It also tracks the trends over several decades. The employment in downstream industries that use Illinois aggregates and the wages they paid make a major economic contribution to Illinois that, although not quantified by the BEA statistics, is very real.

The economic crisis in 2008 affected the aggregate industry seriously as construction activity declined precipitously. Crushed stone production declined from 78 million metric tons in 2007 to 45 million metric tons in 2013. Sand and gravel production likewise declined from 32 to 18 million metric tons. Portland cement production fell by two thirds. However, both the production and price of industrial sand increased significantly as a result of the rising demand for frac sand. Consequently, despite the declining value of traditional aggregates, the total value of all non-fuel minerals in 2013 was about $1.1 billion, as compared with $1.2 billion in 2007. As the construction industry recovers from the crisis, supported by low interest rates, the production of crushed stone, sand and gravel, and portland cement is expected to recover. If the demand for frac sand continues to remain strong, employment in the non-fuel minerals industry may increase, thereby increasing the positive multiplier effect on the Illinois economy.

Downstream from the Illinois aggregate and other non-fuel minerals industry are an array of businesses, many of which are related to the construction industry. Beyond construction itself, they include the manufacture of cement, glass, bricks, pavement blocks, pipes, insulation, and roofing shingles. Aggregates, specifically some specialty sands, are used in the oil and gas industry for rock fracturing. Coal mines use limestone as a fire retardant, and coal-fired power plants use lime and limestone to remove sulfur from smokestacks. Foundries use sand to make molds, and agricultural uses include lime for controlling soil acidity and supplementing poultry feed.

The nonmetallic mining industry in Illinois, primarily the aggregate industry, employs more than 4,900 persons, nearly half of whom work in businesses directly supporting the mining operations. Together, their payroll in 2012 exceeded $280 million. Other downstream businesses listed above employed more than 227,000 persons in 2012. For every person employed in the aggregate industry, about 46 others are employed in the downstream industries that use aggregates in one form or another. Their annual payroll exceeded $14.2 billion, or 80 times that of the aggregate industry. Most of the downstream employment and payroll is in the construction industry itself. The tax revenues generated as a result of the $14.2 billion payroll alone make a significant contribution to the state's budget. Continued significant economic benefits accrue to Illinois communities as a result of the spending by recipients of the payrolls as the ripple effect of payrolls and spending by auxiliary businesses continues.

The upstream economic multiplier effects of the Illinois aggregate industry can be quantitatively and causatively attributed to the Illinois aggregate industry as summarized below:

Employment effects:

- 12.2 to 12.3 jobs are created in Illinois, including those in the aggregate industry, for each $1 million worth of aggregates sold.
- 1.74 to 1.86 additional jobs are created in Illinois for every single job in the aggregate industry.

Earning effects:

- $0.60 to $0.62 in wages is paid to Illinois workers, including those in the aggregate industry, for every $1 worth of aggregates sold.
- $1.41 to $1.47 in wages is paid to workers outside the aggregate industry for every $1 paid in wages to aggregate industry workers.

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