

*University of Wisconsin-Madison*  
*Department of Agricultural & Applied Economics*

Staff Paper No. 565

May 2012

**Frac Sand Mining and Community Economic Development**

By

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**AGRICULTURAL &  
APPLIED ECONOMICS**

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**STAFF PAPER SERIES**

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Version 1.4

## FRAC SAND MINING AND COMMUNITY ECONOMIC DEVELOPMENT

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Support for this work was provided in part by the College of Agricultural and Life Sciences, University of Wisconsin-Madison, and the University of Wisconsin-Extension, Cooperative Extension. We appreciate discussions with Carl Duley, Pat Malone and Tim Jergenson during the initial stages of this work. We are indebted to Matt Kures for the mining employment data. Ashleigh Keene and Anna Haines provided helpful comments on this version of the study. All errors are the responsibility of the authors.

## FRAC SAND MINING AND COMMUNITY ECONOMIC DEVELOPMENT

### Summary of Findings:

- Mining, as an industry within the U.S., remains inherently unstable through the “flickering effect” but the level of instability seems to be declining over time.
- Ownership structure of the mining companies and the resource itself greatly influence the degree of economic impact and subsequent growth. Non-local ownership is generally associated with smaller economic impacts and lower local growth levels.
- The growing pool of “resource curse” literature suggests that robust economic growth and development from resource extraction activities should be considered the exception rather than a general rule.
- Communities that are more heavily dependent on mining for employment tend to experience greater negative impacts after the mines close than positive impacts while the mines are in operation.
- One must guard against making blanket generalizations about the impact of mining on the local community. In many ways mining can provide well-paying jobs leading to lower levels of poverty. But on the other hand, mining activity appears to be associated with poorer overall health levels within the community.
- For remote rural counties we have weak evidence that counties more heavily dependent on mining for employment will tend to have a slower population growth rate. There is more consistent evidence that mining has a positive impact on employment and income growth rates.

### Issues to Consider:

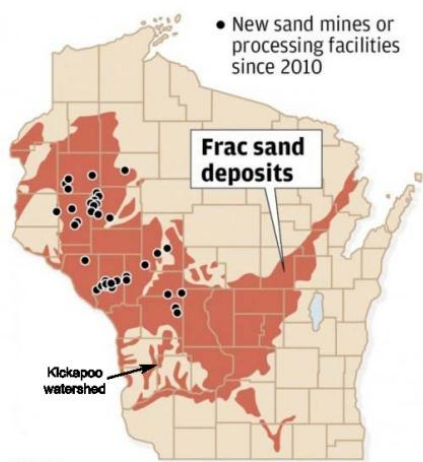
- Are mining operations consistent with other sources of economic activity within the region?
- Is the public infrastructure (transportation networks) sufficient to support the mining operations? Are sufficient public resources (i.e., tax revenues) available to maintain infrastructure in the face of increased deterioration through usage?
- Is there a sufficient pool of labor to meet the needs of the mining operations and replace workers who transfer into the mining industry?
- Is the community making adequate investments to build on the economic activity generated by mining operations?
- Is the community implementing strategies to adjust to mine closures? In other words, are post-mine plans in place and being acted upon?
- Is the community learning from the experiences of other communities that have experienced this type of development?

## FRAC SAND MINING AND COMMUNITY ECONOMIC DEVELOPMENT

*A controversial natural gas mining technique called "fracking" is creating a boom in Wisconsin sand mines with more than 20 new mines proposed, including some as large as 500 acres or more. While the mines bring jobs, they also bring dust, traffic and other problems the state Department of Natural Resources and local governments aren't prepared to deal with, residents and government officials said at a recent conference on "frac sands." Wisconsin State Journal, (December 11, 2011).*

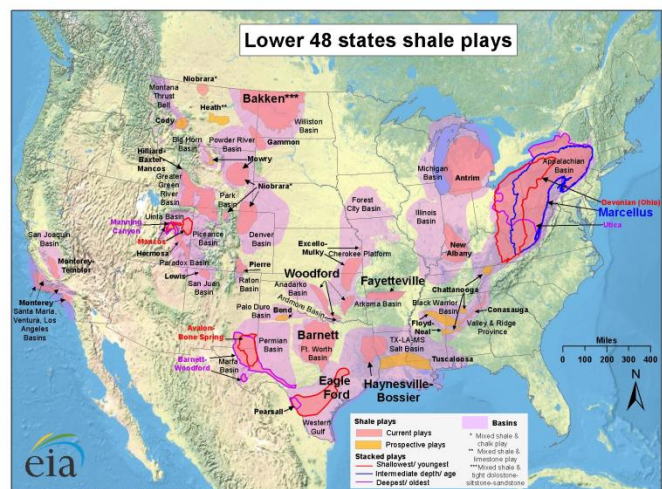
*The rolling hills and scenic bluffs of western Wisconsin and southeastern Minnesota hide a valuable resource that has sparked what's been called a modern-day gold rush. Largely overlooked in the national debate over fracking is the emerging fight in the U.S. heartland over mining "frac sand," which has grains of ideal size, shape, strength and purity. Mining companies say the work provides good jobs in rural areas, but some residents fear the increase in mining could harm human health and the environment. USA Today, (January 5, 2012).*

As the national economy struggles to recover from the "Great Recession" of 2008-2009 the high price of oil, and to a lesser extent natural gas, has created economic opportunities for many rural communities. The process of hydraulic fracturing, or "fracking", to remove oil and gas from rock formations has created "mining booms" in large parts of the western Appalachian Mountains (the Marcellus fields in the Appalachian Basin) and western North Dakota and eastern Montana (the Bakken fields in the Williston Basin) to name a few. While there is limited possibility for the extraction of shale deposited oil and gas for Wisconsin, the engineering of the extraction process requires sand with specific characteristics that is in abundant supply in many parts of Wisconsin. The surge in demand for this "frac sand" has created what appear to be significant economic opportunities for the western and central parts of Wisconsin.



SOURCE:  
Wisconsin Geological &  
Natural History Survey

State Journal



Source: Energy Information Administration based on data from various published studies.  
Updated: May 9, 2011

Given the deep economic pains of the last recession, these economic opportunities are being promoted by both mine developers and many local residents as a source of well-paying jobs. Many of these proposed mines tend to be located in more rural and low income areas and the job generating potential has overridden any environmental concerns. In addition, Wisconsin's original economic base centered on mining (i.e., the Badger State is derived from early lead miners living in "dugouts" during winter months, like badgers) there is an affinity for the mining industry. Over time, however, mining no longer served an integral part of the Wisconsin economy and has been replaced with industries that thrive on the natural amenities of the state. This includes tourism and recreation as well as retirement migration. In terms of its natural resources, Wisconsin has slowly shifted from an extractive based economy (e.g., mining and forestry) to a non-extractive based economy (e.g., recreation and tourism).

Arguments have been made that these two competing uses of Wisconsin's natural resources are not compatible and the promotion of one comes at the expense of the other. In addition, for many parts of rural Wisconsin mining may be in competition with agriculture for land resources. This conflict comes to light when one considers how many Wisconsin communities envision themselves. Consider, for example, the Vision Statement of St. Croix County (Chapter 31, page 108):

St. Croix County is a diverse and vibrant hub set amid the Upper Mississippi River and scenic coulees. Within this setting are valuable natural, agricultural, cultural, transportation, educational, and economic resources. These resources provide residents, businesses, and visitors distinct urban amenities and small-town livability. Preserving these resources and strengthening the connections between them is the foundation for maintaining and enhancing quality of life and economic opportunity.

Many rural towns have embraced attributes such as scenic beauty, open green space, agriculture and wildlife as key to the character of their community. For many rural residents, the economic opportunities presented by the frac sand mines have created a "classic" jobs versus environment type of debate.

Unfortunately, there is no clear cut answer to this perceived trade-off. For one community, the notions of private property rights and the ability of a land owner to use their land as they see best, coupled with the creation of employment opportunities, may override any concerns about preserving natural amenities and the environment. For other communities, the opposite may hold true. Regardless of specific circumstances, ideally we would hope that local decision-makers and concerned citizens have access to the best information available and a deliberate decision-making process. The intent of this study is to provide some insights into the economics of the proposed mines with particular attention to economic growth and development opportunities associated with the mines. We are not so much interested in the business viability of the frac sand mines themselves but rather the impact these mines may have on the growth dynamics of the local regional economies. We look at two specific elements: (1) the stability of the mining industry and (2) its association with economic growth.

Many rural communities that are associated with large mining operations are often described as “boom-bust” type of communities. The mining of a finite resource by definition has a finite economic horizon: the resources that are mined will eventually be depleted and the mines will close. The proposed copper-zinc mine in Crandon, Wisconsin, for example had an estimated 30 year life after which the resource would be depleted and the operation closed. Another form of the “boom-and-bust” cycle that characterizes some mining operations is the “flickering” of operations. Depending on the commodity prices of the material being extracted the operations of the mine may be shut-down for periods of time. As commodity prices flicker or fluctuate employment at the mine also flickers or fluctuates creating instability in the local economy. Concern has also been expressed over the type of economic growth that may be associated with mining development. Some, such as Cushing (1999), suggest that many of the jobs are low skilled and attract a labor force that limits future economic growth. In addition, because of the “flickering” of mining operations, the potential for spin-off business development is limited. The growth in consumer businesses, such as restaurants and beauty/barber shops, are not realized because of the inherent instability of the mining operations.

In this study we hope to shed some light on the community economic dimension of mining by examining the role of mining activities in economic growth and stability. We use national as well as U.S. county level data to seek insights into these questions. In the next section of this study we provide a simple review of some of the available literature. By reviewing what others who have studied mining have found we can gain some of those insights and help us think the problems through. This review is followed by a general discussion of growth in the mining industry at the national level with particular attention to issues of stability. We then explore the influence of mining on community well-being with a comparison across a range of socioeconomic and health characteristics of the community by dependency on mining for employment. Here we ask a simple question: does higher dependency on mining for employment influence the well-being of the community? In the fifth section we report on the results of a simple economic growth model where we focus on the role of dependency on mining for employment. In our statistical work in sections four and five our working definition of mining is all extractive industries with the exception of oil and gas extraction, specifically data for NAICS code 212. We narrow our definition to make our work more in line with sand mining. We conclude this study with a review of our findings and outline some of the issues that we have not been able to address.

### **What does the existing research tell us?**

Surprisingly, there are only a handful of peer reviewed studies that examine the impact of mining operations on the local community within the academic literature. While there were a significant number of case studies in the sociology literature in the 1970s and 1980s and a growing literature seeking to understand the impacts of large mining operations in developing countries, there are few rigorous studies of how mining operations impact communities in the U.S. Much of the available research is in the form of consultants’ technical reports and what is referred to as the “grey” literature. While many consultants’ reports are very well done it is difficult to draw generalities from them because their funding sources (mining companies and/or environmental advocacy groups) challenge their

objectiveness. As Weinstein and Partridge (2011) have noted, studies funded by extractive industries tend to be flawed towards overstating potential economic benefits. In particular, industrial studies typically overemphasize employment growth, while ignoring labor displacement from other sectors. The “grey” literature is composed of studies presented at academic/professional meetings or student research projects that are never published or stand the test of peer review.

The mining literature that focuses on developing countries, often in the context of the “resource curse thesis”, offers several reasons why many poorer nations aggressively pursue mining as an economic growth strategy. Developing countries tend to view natural resources through classical theoretical perspectives, specifically, striving to achieve their comparative advantage as outlined in international trade theory (Bridge 2008). Often times the nation’s endowment of natural resources defines their comparative advantage and as a consequence, their economic growth strategies. In the case of subsurface mineral resources an analogy is often made with “buried treasure” with technology providing the “key” to opening the national vault (Bomsel 1990). As noted by Gunton (2003) as well as Bridge (2008) the external sources of investment for mining projects creates a spread effect which drives economic expansion, moving the regional economy from a lower level equilibrium of development to a new equilibrium of higher levels of socio-economic well-being. The initial investments jump-start the economy and the extraction and export of the resource spurs a cycle of economic growth. For many parts of Wisconsin the comparative advantage and “buried treasure” are the unique sands that are required for extraction of some oils and gas deposits through fracking technologies.

Unfortunately, much of the research that examines mining within developing nations often conclude that because of the ownership structure of the mining firms and lax if non-existent environmental or labor safety standards, very little of the economic benefits are retained in the local economy. The economic historian Innis (1956) found that in the case of Canada specialization around resource extraction did not drive economic diversification but rather a form of dependency on an unstable industry. As noted by Bridges (2008) the growing pool of “resource curse” literature suggest that robust economic growth and development from resource extraction activities should be considered the exception rather than a general rule (Ross 1999; Sachs and Warner 1999; Watts 2005; Rosser 2006). Indeed, in the international development literature, mineral resource extraction as a mode of regional development has become a “pariah” (Humphreys, Sachs and Stiglitz 2007).

It is not clear, however, that the “resource curse” that dominates the international development literature is directly transferable to rural Wisconsin. First, the institutional rules that govern extractive industries in the U.S. and Wisconsin are more established and more conducive to minimizing environmental damage. This is consistent with Mehlum et al. (2006) who argue that institution quality is a large determinant of the economic effects of resource extraction. Labor laws prohibit the exploitation of workers which is often at the heart of the “resource curse”. If mining operations damage neighboring lands, well established law allows recourse through the courts. Such recourse, or the threat of legal recourse, will motivate mining operations to minimize negative spillovers or externalities. Second, many developing countries lack the institutional structure to capture the economic opportunities created by extractive industries. For example, in Wisconsin local economic development organizations may be in a

better position to build on the economic activity that is generated by the mining operations. Third, in the international development setting nearly all of the extracted resources are sold in the international markets and hence exposed to movement in exchange rates and trade policies. While the frac sand industry is not directly involved in foreign export markets, the oil and gas industry that uses frac sands are sensitive to international trade forces.<sup>1</sup>

Surprisingly, there are only a handful of studies focused on discerning evidence of the “resource curse” within the U.S. Papyrakis and Gerlagh (2007), using state-level data, note that resource abundance tends to decrease investment and the quality of schools and increase overall corruption within policing authorities, thereby stunting state level growth. Specifically, the authors find for every 1% increase in income from mining, the annual growth rate decreases by .047 for the 1987 to 2000 period. Further, James and Aadland (2011) adds to the “resource curse” literature by using U.S. county level data and find that resource dependent counties contrive anemic growth relative to non-resource dependent counties. These studies, however, largely ignore the specific nature of extractive industries. In the James and Aadland study, a resource dependent county is modeled in their growth equations as the percent of earnings in agriculture, forestry, fishing, and mining. Thus, any conclusion extrapolated from their results concerning counties with a significant share of income derived from mining operations should be taken lightly.

Unfortunately, associated literature that examines how mining specific resource extractive industries influence regional economic growth and development within a U.S. setting is even sparser. One of the first studies to provide a comprehensive analysis was undertaken by the USDA Economic Research Service which compared and contrasted “mining dependent” counties (those where 20 percent or more of total labor and proprietor income came from mining) to other nonmetropolitan counties across several socioeconomic factors (Bender, et al. 1985). The researchers found that mining dependent counties had higher population growth rates, higher incomes, and fewer people receiving social security than the nonmetropolitan average. Mills (1995) found that earnings per worker were higher in mining than in other sectors, including both nonmetropolitan and metropolitan counties.

But Weber, Castle and Shriver (1987) found that U.S. counties with energy-related mining experienced growth in employment and earning during the mining boom years 1969-1985, but counties with metal mining experienced declines during those same years. Nord and Luloff (1993) decomposed mining into three types (coal, petroleum and “other”) and looked at three regions of the U.S. including the south, Great Lakes and western counties. At the time of the 1980 census, Nord and Luloff generally confirmed the results of Bender, et al. (1985) but post the 1980 time period the economic implications of mining

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<sup>1</sup> Despite relatively high international prices for natural gas (NG), domestic prices are still fairly insulated because natural gas must be converted to Liquefied natural gas (LNG) to be shipped, which is an extremely expensive process. There is some evidence that domestic over production has depressed natural gas prices in the U.S. placing downward pressure on new drilling. Still, natural gas extraction may continue even if NG (methane) prices fall even further because two of the byproducts that come out with methane (butane and propane) remain profitable.



deteriorated across all three types of mining and all three regions. Indeed, by 1990 all mining dependent counties experienced faster growth rates in poverty than other nonmetropolitan counties. These studies suggest that the impact of mining on local economic growth is sensitive to the time period examined. One could reasonably conclude that this observation speaks to the instability of the mining industry itself.

Related literature concerning the boom-bust cycle of extractive industries is telling of the instability that may result from the volatility of world markets. After studying the coal boom and bust of the 1970s and 1980s, Black et al. (2005) noted that the negative spillovers of the coal bust were considerably larger than positive spillovers contrived during the boom years. In particular, the authors found that for every 10 jobs created in the coal sector during the boom, fewer than two jobs were produced in other sectors of the local economy. Conversely, for every 10 jobs lost in the coal sector during the bust, roughly 3.5 jobs were lost in adjoining sectors of the economy.

Lockie et al (2009) conducted a longitudinal study of the Coppabella coal mine in Queensland, Australia and found increased anti-social behavior, such as traffic-related accidents and increases in criminal activity, a few years after the boom in commodity prices. Lockie and colleagues also found that the mining operations created shortages of skilled labor in other industries. Weber (2012) estimated the gains in counties experiencing a boom in natural gas production. He found modest employment improvements, suggesting that only 2.35 jobs are created for every million dollars of gas produced thus generating an increase in employment growth of 1.5 percent. In a contrasting study, Marchand (2010) found that total employment grew 6.5 percent for the 1996 to 2006 oil and gas boom in Western Canada. Notably, he finds substantial increases in earnings per worker and decreased levels of poverty. These positive conclusions, however, are reflective of the “boom” years. Marchand notes that earnings per worker declined during the bust years, which had negative impacts in construction, retail and service sectors. In essence, the mines “pilfered” workers from other industries creating labor shortages. Indeed, in Wisconsin there is some antidotal evidence that local governments are losing highway and public works department workers to the operating sand mines and are having difficulty replacing them.

An extensive sociological literature tends to find unfavorable effects related to increased mining activity within a locality. Freudenburg and Wilson (2002) pooled known peer reviewed qualitative and quantitative U.S. specific mining studies and found that the majority indicate adverse economic effects in mining communities. The authors note, however, that there exists regional variation in the effects of mining activities. In particular, studies examining mines in the Western region of the United States typically reach more favorable conclusions than those focusing on the rest of the country. Wilson (2004) suggested that large discrepancies exist in the literature because many studies fail to consider specific characteristics of mining activities, therefore not capturing many potential socio-economic consequences. Stedman et al. (2004), studying resource dependence in rural Canada, also noted the need for models to incorporate regional specifics in attempting to quantify the effects of mining or other extractive activities. For example, the size of the mining operation, the remoteness of the mine, or the presence of other non-mine related economic activities. Freudenburg and Gramling (1994) suggest that

the regional variation in the impact of mining operations on the local communities hinges on the extent to which the mining industry is integrated into subsequent economic and infrastructural development.

Sociologists have tended to highlight the inherent interplay between the instability of mining communities and the volatility of commodity prices. In his foundational study, Freudenburg (1992) portrayed quite starkly the relationship between local economic growth and the downward trend in world commodity prices. He suggests that due to “cost-price squeezing,” production may cease even with abundantly available supplies of raw materials. That is, world price for the commodity drops below an economically feasible price to extract them, thus stunting local economic growth. What Freudenburg is describing is the “flickering” of the local economy as the mining operations respond to commodity prices. Wilson (2004) suggests Freudenburg’s theory should be modified to include specific characteristics of the commodity and local economy, before unquestionably accepting the link between volatile world prices and instability or flickering in the local economy. These observations are particularly relevant to frac sand mining because of its use in oil and natural gas extraction; if the prices of these two commodities drop below a certain threshold they will become unprofitable and the demand for frac sand will disappear. Consider, for example, the recent drop in natural gas prices has resulted in a significant decline in new drilling for natural gas. This in turn lowers the demand for frac sands.

The available literature leaves us with as many questions as it does answers.

- It is clear that the characteristics of the community where the mine is located matters to how the mine will impact the community. Large mines located in isolated rural communities will have a different impact than smaller mines in more densely populated areas.
- The ability of local institutions, such as local governments and economic development organizations, to build on the presence of the mine while it is in operation can dramatically alter the short- and long-term impacts of the mine. For example, a community that implements long-term development strategies anticipating a post-mine community will be better off than a community that does not anticipate the closing of mining operations.
- The literature also is clear that communities that experience sudden booms will also experience short-term difficulties related to an influx of migrant workers such as shortages in rental properties, increases in certain types of crime, and shortages in labor as workers shift to employment opportunities in the mines.
- Finally, communities may experience socioeconomic stresses from flickering as mines expand and contract operations in response to commodity prices.

## General trends in the mining industry with a focus on stability

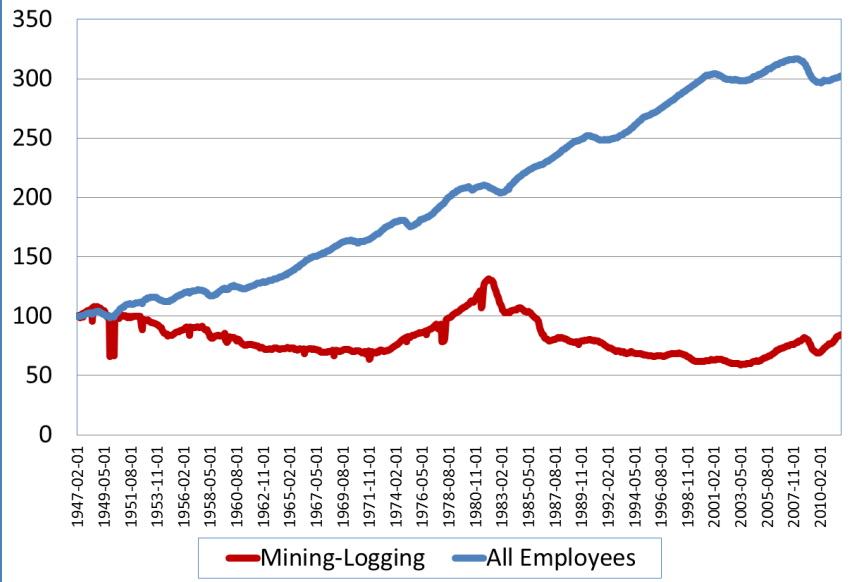
Prior to making any decision on the viability of frac sand mining as a potential economic growth and development strategy, it is insightful to assess the overall trends in the mining industry. While a community or region may have what economists refer to as a comparative advantage in one particular type of industry, it does not necessarily mean that it is a viable option for the community.

Consider manufacturing as an example of a dynamic industry whose role in economic growth and development is shifting. For generations manufacturing was a major source of employment opportunities for not only urban but also rural areas across the U.S. Beginning about 30-40 years ago manufacturing as a source of employment began a fundamental transformation. Three things came together to foster this transformation: (1) opening of lower cost production opportunities in developing countries, (2) a shift in the national economy from a goods to a service producing (i.e., consumer demand is shifting from

goods to services), and (3) a shift to more capital intensive technologies (e.g., computer operated equipment and robotic technologies) and away from labor. While manufacturing may remain a source of well-paying jobs its potential for job growth is becoming increasingly limited.

Consider national overall employment and mining employment growth from 1947 to the end of 2011

**Figure 1. National Employment: Growth Index**

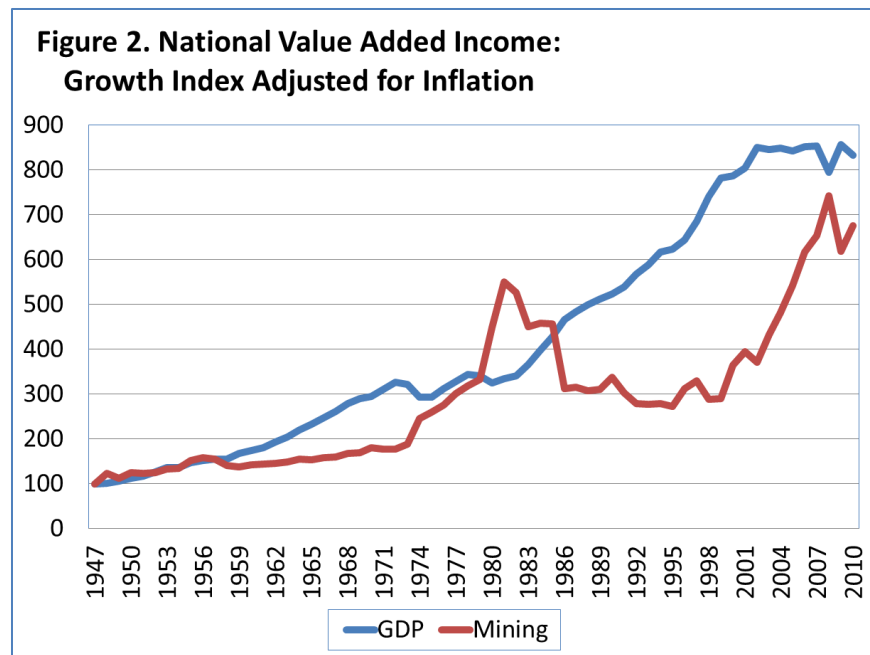


(Figure 1). Unfortunately, the national monthly employment data combines all mining and logging activities into one industry. Nationally, overall employment grew by 200 percent over this time period but mining-logging employment actually decline by a modest amount. From 1947 to the early 1970s there was a consistent decline in mining-logging employment but strong growth throughout much of the 1970s. This growth period in the mid to late 1970s was largely driven by increasing energy (oil) prices following OPEC's decision to reduce production. This growth in mining employment in this time period also sparked a surge of research interest in the impacts of mining on local communities. But as energy prices, particularly oil prices, declined in the mid-1980s the downward trend in mining employment returned. These data point not only to the sensitivity of mining to commodity prices but also to the potential for boom-bust cycles in mining dependent communities.

Beginning in about 2003 there has been modest growth in mining-logging employment. While this data is not refined enough to draw definitive conclusions, it appears that the upward trends are associated with rises in energy costs and the expansion of domestic energy production. It appears that the increase in energy related mining activities of the late 1970s is repeating itself over the past few years. This observation corresponds with the current demand for frac sand mining.

An alternative metric to examine the trends in the industry is to look at changes in income generated by the industry (Figure 2). In essence we are mapping growth in total gross domestic product (GDP) and mining's contribution to GDP. *Here the national data reports separates mining from logging so a direct comparison between the employment trends (Figure 1) and the income or GDP trends (Figure 2) needs to be conducted with care.*<sup>2</sup> In addition, the income data reflects commodity prices which can “artificially” inflate and deflate income data. For example, income derived from a consistently producing oil or gas well (i.e., jobs attached to the well or mine may be constant) will fluctuate with commodity (oil or gas) prices. In other words, although employment may be fairly constant income will fluctuate.

Given these provisions an overlap of mining (and logging) employment patterns with value added income reveals parallel patterns. Prior to the energy boom of the 1970s the mining industry was exhibiting modest growth relative to the national economy. The spike in the early 1980s reflects the spike



in energy related mining, such as oil drilling in the Oklahoma-Texas region. As energy prices declined throughout the 1980s and much of the 1990s the size of the mining industry, as measured by value added income, declined and stagnated. From about 2001 there has been very strong growth in income from the mining sector.

These patterns point to two generally findings. First, growth in the mining industry as measured by value added income, particularly over the past decade, has not been matched by growth in mining employment. In addition to fluctuation in commodity prices this observation is perhaps best explained by shifts in the production technologies in the mining industry. An industry that could at one time be described as labor intensive is moving toward a more capital intensive production process. The

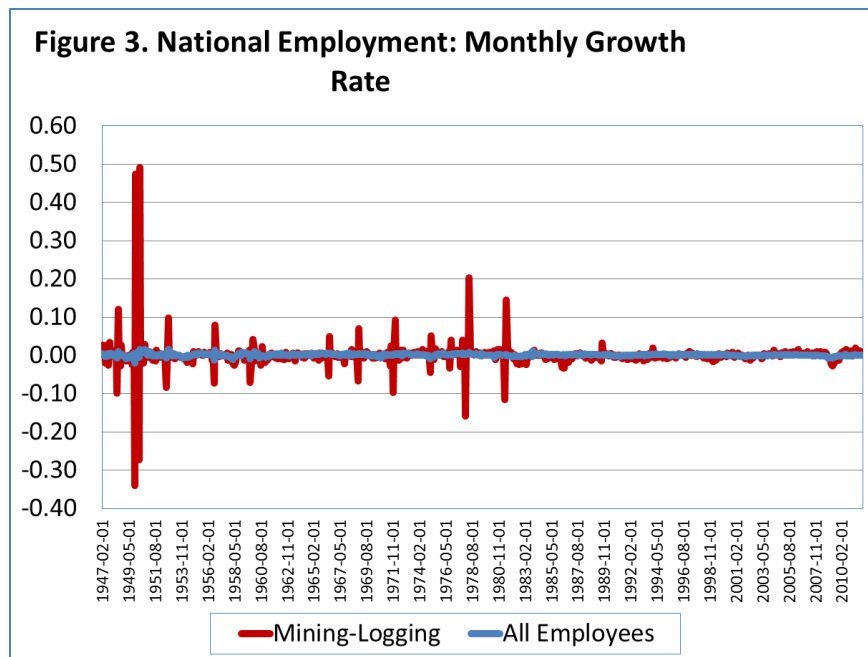
<sup>2</sup> It is important to note, again, that the employment data is monthly while the income data are annual and the employment data merges mining and logging while the income data includes only mining.

implication for frac sand mining in Wisconsin is that the trend within the industry is to adopt labor saving technologies over time.

The second observation is that mining appears to be relatively unstable and subject to “boom-bust” cycles. As outlined in our review of the literature above, a consistent finding is that communities that are heavily dependent upon mining often experience economic instability. The “boom-bust” generally is associated with opening (the “boom”) and closing (the “bust”) of the mine facility. Because many mines are located in remote rural areas the opening and closing of the mine can have dramatic impacts on the community. A second element of the stability issue is the “flickering” effect as described by Freudenburg and Wilson (2002). Here the operation of the mine is sensitive to the prices of the commodity (materials) being extracted. This is particularly true for metal mining where the mining operation can be scaled up or down (i.e., flicker) based on commodity prices.

One way to explore the stability of the mining industry is to measure the percent change in employment and income in mining from one time period to the next. The greater the fluctuation in these changes the greater the level of instability within the industry. The monthly changes in total national employment as well as employment in mining and logging is provided in Figure 3.

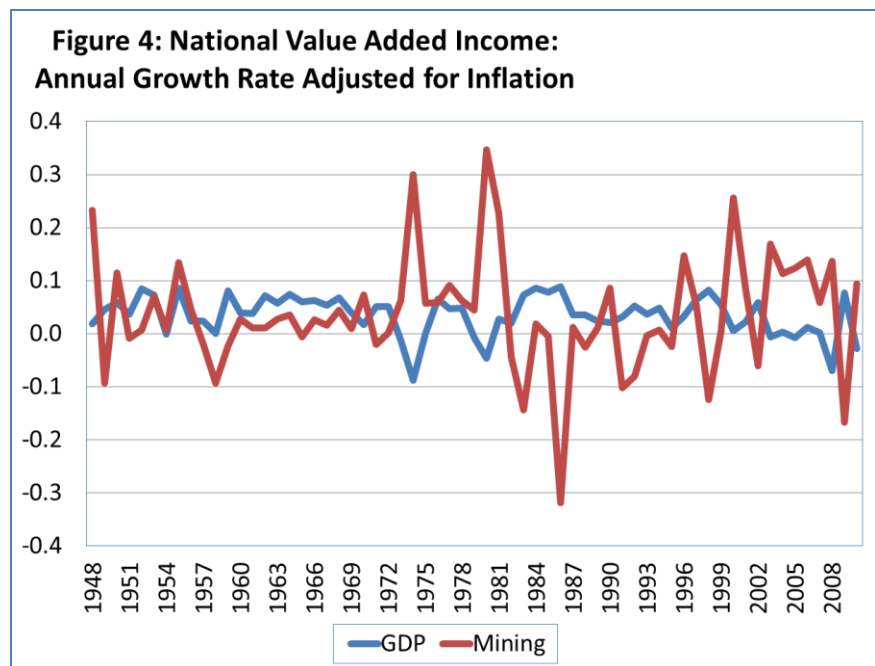
A simple visual examination suggests that the monthly swings in employment are much higher in mining and logging compared to total employment, particularly prior to the early 1980s. The maximum monthly increase for total national employment was 1.6 percent and 49.1 percent for mining and logging while the minimum increase for total employment was -1.9 percent and -34.0 percent for mining and logging. The standard deviation of the average monthly changes is .0344 for mining and logging, but only .0030 for total employment. The last set of statistics points to the instability of the mining and logging industries and is consistent with the findings of many of the studies reviewed above, particularly the work of Freudenburg and his colleagues.



While the mining and logging industry is still relatively unstable compared to total employment, the level of instability appears to dramatically decline in the 1980s and up to the most current data. While it is not clear why the industry has reduced its relative level of instability, one possible explanation might be the adoption of more capital intensive technologies and the movement away from labor.

If we look at the annual percent change in national value added income from mining the instability of the industry is readily evident (Figure 4). The maximum increase in mining income was 34.7 percent while it was only 8.9 percent for total or aggregate national value added income. The smallest increase, or in actuality a decline, was -31.8 percent for mining and only -8.8 percent for total income. The more important statistic is the standard deviation of the annual changes which ranges from 0.037 for the total economy and 0.107 for mining. Here again, the larger standard deviation for mining suggests that the industry is more unstable than the overall economy, therefore providing more evidence for instability in the mining industry.

While the insights gained here are helpful in understanding the overall nature of the stability of the mining industry, the analysis has one rather significant caveat. Specifically, the absolute scale of the mining industry to the overall economy can lead to a potential problem of scale. For example, consider an industry that has 1,000 jobs and another that has 100. Suppose that both industries increase employment by 10



jobs. For the larger industry adding 10 jobs creates a one percent growth rate while for the smaller industry adding 10 jobs creates a 10 percent increase. Because the mining industry is relatively small compared to the overall economy the percentage changes will by definition be larger than the national economy. Even with this important caveat, the simple results presented here coupled with the available literature reviewed above, one can safely conclude that mining is an inherently unstable industry and can create instabilities in the local economies.

**Does mining influence overall community well-being?**

Beyond the jobs and income generated by mining operations, one of the concerns identified in the academic literature outlined above centers on the impact of mines on the overall well-being of the

community. Sociologists (e.g., Freudenburg and Wilson 2002) who have extensively studied the impact of mines on community well-being point to concerns about the quality of community life. To gain some insights into these concerns we explore how dependency on mining for employment is associated with different measures of community well-being ranging from poverty and crime rates to a range of health metrics such as adult obesity rates and low birth weights.

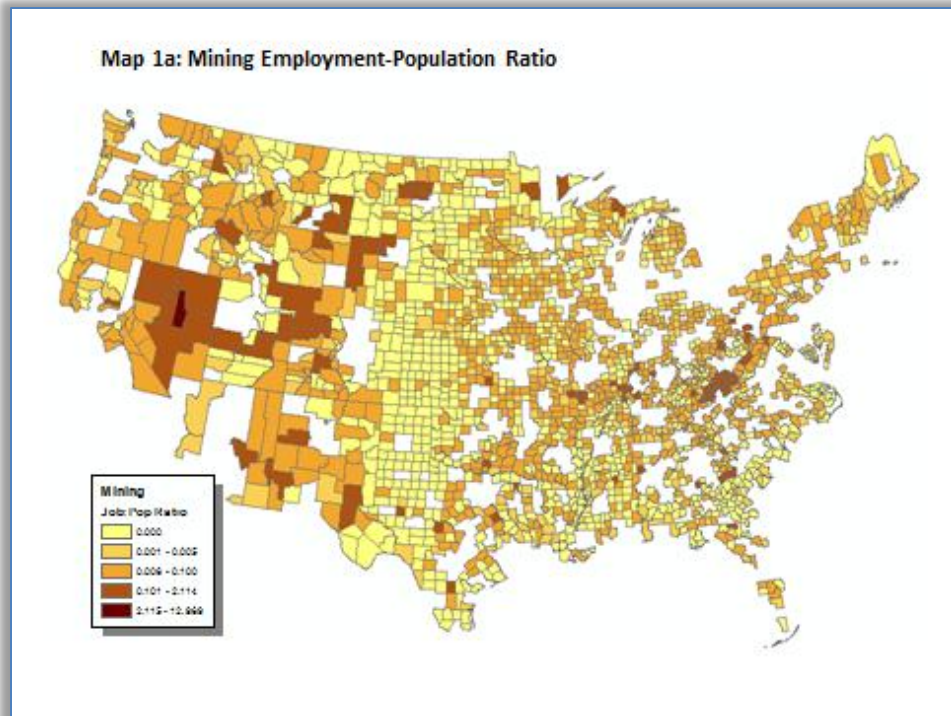
To do this we use nonmetropolitan U.S. county level data from a range of sources covering the years 2004, 2005 and 2006. Specifically, *we use employment data for NAICS code 212 which includes all mining activities except for oil and gas extraction*. The types of mining included in this analysis are coal, metal ore and nonmetallic mineral mining and quarrying. This latter category includes sand mining which is of particular interest given the Wisconsin situation. We explicitly exclude oil and gas extraction because the industry is fundamentally different from sand mining. An analogy might be crop and animal production in agriculture: both are agricultural industries but the production technologies and relationships to the local economy are fundamentally different.

There are two ways to proxy the importance of mining employment to the local (county) economy: (1) share of total employment in mining and (2) the number of mining jobs per capita (or mining employment to population ratio). These two simple metrics of mining employment dependency, however, are very highly correlated (see scatter plot in Appendix Figure A). This means that using both measures to examine the socioeconomic and health data will provide parallel results. Thus we proceed in two steps. First, we use the number of mining jobs per capita (i.e., number of mining jobs in the county divided by the county population) to look at correlations between mining dependency and our set of socioeconomic and health measures.

Second, we use the share of total employment in mining for the county divided by the national share which provides us with a location quotient. The location quotient centers on one and is a measure of economic specialization. If the location quotient is greater than one, then there is a larger share of employment in mining than we would expect (i.e., national average), or there is a certain level of specialization in the mining industry. If the location quotient is less than one, there is a smaller amount of activity than expected. We proceed by grouping counties into two sets: those with a location quotient greater than one (i.e., specialized) and those with a location quotient less than one. We can then compare and contrast those two samples.

**Mining jobs per capita** The typical nonmetropolitan county contained in our data had an average of 0.030 mining jobs per capital with a standard deviation of 0.303. Note that the standard deviation is nearly ten times larger than the mean or average. This observation points to a very wide dispersion of mining employment across the U.S. For example, 44.6 percent of nonmetropolitan counties have no mining employment and a smaller handful have very large mining operations given the population size of the county. There are a handful of counties, including Eureka, Nevada, Stillwater, Montana and Greenlee, Arizona that have more mining jobs in the county than people living in the county. An examination of Map 1a reveals that mining activities are not solely limited to the coal mining region of the Appalachia's or the mountainous west, but rather are more evenly distributed across much of the



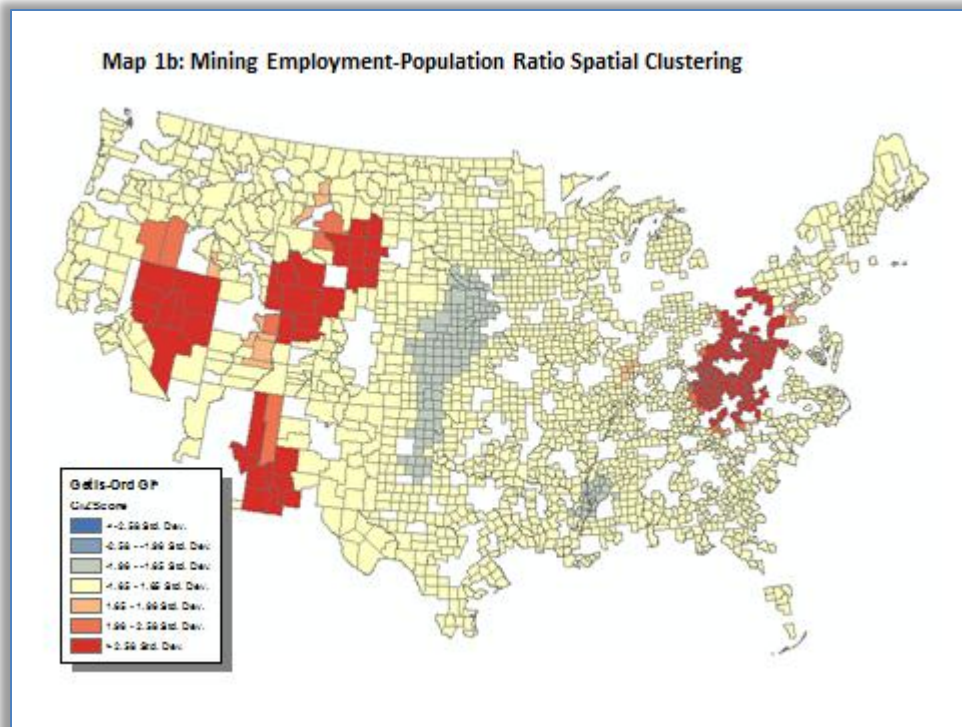


U.S. Outside of the Great Plains from southern Texas to the Canadian border there are mining operations scattered throughout the U.S.

Use of a spatial statistical tool referred to as the Getis-Ord statistic we can test if the patterns observed in Map 1a are statistically

significant. A high value of the spatial test statistic is associated with spatial “hot-spots” where there are strong spatial clusterings. Low values of the statistic suggest spatial “cold-spots” or areas where the mining industry is not located. Areas where the spatial test statistics are between the critically large and small values, the results are deemed statistically insignificant or there are no statistical significance to

the observed spatial patterns. The results of the computation of these spatial test statistics are provided in Map 1b. There are four clear “hot-spot” clusters: Nevada, parts of Arizona and New Mexico, parts of Colorado and Wyoming, and the coal region of the Appalachia. The western part of





the Great Plains are a “cold spot” and with a small part of Louisiana and Mississippi. One must keep in mind that we explicitly remove oil and gas mining operations from our analysis because they are fundamentally different from frac sand mine type operations.

While there does not appear to be statistically significant spatial clustering of mines outside the Appalachia coal region and parts of the mountain west, there is a wide spread of randomly (i.e., not statistically significant) scattered mining operations throughout much of the U.S. Many of these mining operations, however, are small scale. Of those nonmetropolitan counties that have some level of mining, 12.9 percent have less than ten mining jobs. One must recall that our definition of mining includes gravel pits which are widely common in many counties. Thus, the mining industry we examine ranges from small gravel pits to large coal and mineral mining operations.

As discussed above we look at a set of economic metrics such as the overall poverty rate, the child poverty rate, unemployment rate, crime rates and educational attainment. In addition we examine a variety of health metrics including low birth weight, percent of persons who smoke, obesity rates, and teen birth rate among other metrics. Our two measures of statistical correlation include the Spearman correlation coefficient and the Kendall Tau b correlation coefficient.<sup>3</sup> A positive correlation coefficient is interpreted as a positive relationship between the level of mining employment and the particular socioeconomic or health metric. The way in which most, not all but the majority, of the metrics are defined, a positive correlation is an indication that higher levels of mining activity is associated with counties that have lower levels of socioeconomic development and higher levels of poor health. ***We cannot infer, from this analysis, that higher levels of mining cause or are the determining factor in the socioeconomic or health factor, simply that there is a correlation.***

Consider first, the correlation analysis for the socioeconomic metrics (Table 1). Here we find mixed evidence of the relationship between mining and socioeconomic well-being. For example, higher levels of mining employment per capita is associated with lower levels of the overall poverty rate as well as the child poverty rate. This suggests that the jobs associated with the mining industry are paying wages that are above the poverty rate. We also find evidence that higher levels of mining activity are associated with lower levels of income inequality (i.e., lower values of the Gini Coefficient are associated with lower levels of income inequality). These three results, taken in tandem, suggest that higher levels of mining employment for a given population will result in lower levels of poverty and higher levels of income equality.

In terms of crime, we find that mining activity is not associated with violent crime (i.e., the relationship is statistically insignificant, hence no discernible relationship), but is associated with higher levels of property crime. Further analysis of the property crime data by type of crime (e.g., burglaries, larceny, etc.) would be required to draw any additional insights. We also find that higher dependency on mining is associated with a higher share of the population having a high school degree but a lower share of the population with a bachelor’s degree.

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<sup>3</sup> Traditionally a Pearson correlation coefficient would be used, but because of the large number of nonmetropolitan counties that have zero mining employment the assumption of a normal distribution of the data is violated. As a result we use the non-parametric Spearman and Kendall correlation coefficients.

Table 1. Simple Correlations: Mining Employment to Population Ratio, Economics

	Spearman	Kendall Tau b
Poverty Rate	-0.0572 (0.0109)	-0.0401 (0.0125)
Children in Poverty Rate	-0.0505 (0.0245)	-0.0349 (0.0292)
Income Inequality (GINI Coefficient)	-0.1209 (0.0001)	-0.0860 (0.0001)
Unemployment Rate	0.0937 (0.0001)	0.0670 (0.0001)
Violent Crime Rate	0.0202 (0.3688)	0.0133 (0.4071)
Property Crime Rate	0.0676 (0.0026)	0.0468 (0.0035)
Persons over 25 with a High School Degree (%)	0.0537 (0.0169)	0.0366 (0.0220)
Persons over 25 with a Bachelor Degree (%)	-0.0540 (0.0163)	-0.0389 (0.0153)

Marginal significance in parentheses.

These latter results are consistent with the conclusions of Lockie et al (2009) who found increased criminal activity and shortages of more educated workers for other industries in their study of mining in Australia.

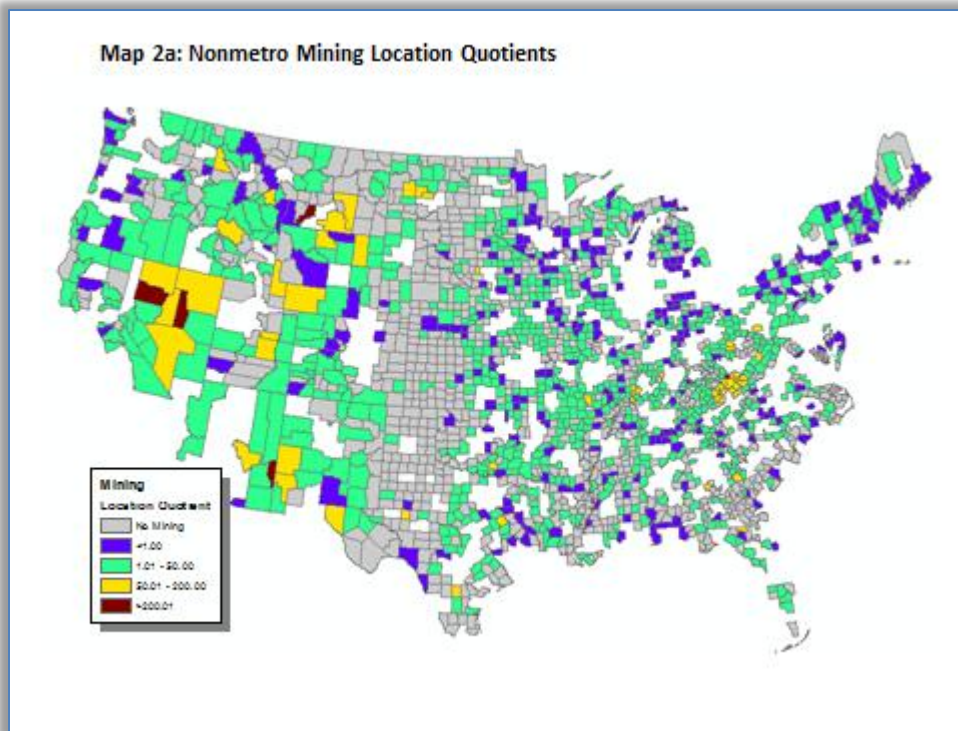
Now consider the relationship between mining activity, again measured by the number of mining jobs per capita, on our set of health metrics (Table 2). As with the socioeconomic analysis there are mixed results with the health data. For example, higher levels of mining activity are associated with lower levels of persons under age 18 without health insurance, low birth weights, adult obesity rates, chlamydia rates, and teen birth rates. All of these results challenge the perception that mining is associated with power levels of health. But there is some evidence suggesting the opposite: higher levels of mining is associated with a higher share of people in “poor or fair” health, poor physical health days, poor mental health days, percent of adults who smoke, and the number of ozone warning days. There is no statistically significant relationship between mining and premature death levels, person of persons who binge drink, or single-parent households.

These results, taken in tandem, suggest “blanket generalizations” that mining will have negative socioeconomic and health impacts on the local community are in error. There is mixed evidence, for example, for lower poverty rates but higher property crime rates or higher rates of adults smoking but lower rates of teen birth rates. The interplay between mining and community well-being, as we have proxied it, is more complex than is often perceived and requires more thoughtful reflection.

Table 2. Simple Correlations: Mining Employment to Population Ratio, Health		
	Spearman	Kendall Tau b
Under 18 Without Health Insurance (%)	-0.1585 (0.0001)	-0.1124 (0.0001)
Premature death (Years of Potential Life Lost)	-0.0217 (0.3463)	-0.0142 (0.3840)
Poor or fair health (%)	0.0582 (0.0190)	0.0419 (0.0168)
Poor physical health days	0.0946 (0.0001)	0.0683 (0.0001)
Poor mental health days	0.1080 (0.0001)	0.0777 (0.0001)
Low birthweight (%)	-0.0437 (0.0657)	-0.0271 (0.1054)
Adult smoking (%)	0.1058 (0.0001)	0.0752 (0.0001)
Adult obesity (%)	-0.0377 (0.0929)	-0.0273 (0.0891)
Binge drinking (%)	0.0017 (0.9478)	0.0010 (0.9548)
Chlamydia rate (per 100k)	-0.0609 (0.0066)	-0.0477 (0.0029)
Teen Birth Rate	-0.1269 (0.0001)	-0.0886 (0.0001)
Single-Parent Households (%)	-0.0068 (0.7607)	-0.0082 (0.6087)
Ozone Days	0.1215 (0.0001)	0.1016 (0.0001)
Marginal significance in parentheses.		

**Mining location quotients**

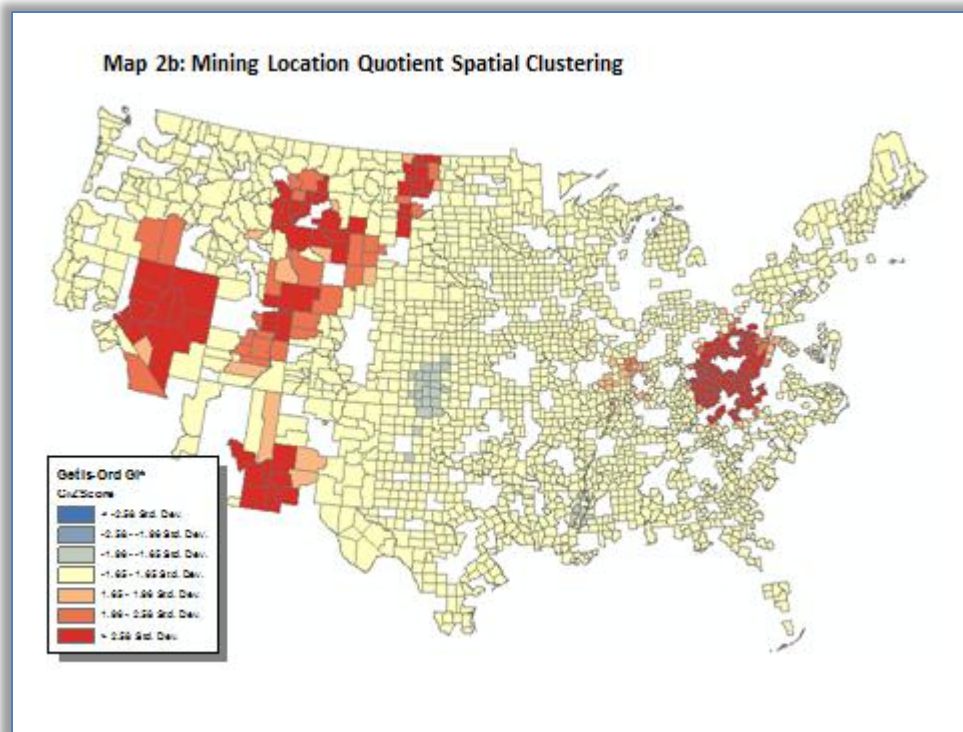
In order to test the robustness of the results centered on the number of mining jobs per capita, we re-examine the data using a different analytical approach. Here we use the share of county employment in mining compared to the national average. As described above the ratio of local (county) share of employment in mining to the national average is defined as the location quotient. If the location quotient is greater than one, then the share of employment in mining for the county is larger than the national average and mining could be described as a “specialty” of a county’s economy. On the other hand, a location quotient less than one suggest that there is less mining activity then the national average. For the analysis presented here we group nonmetropolitan counties into one of two groups: those counties with a location quotient greater than one (i.e., mining counties) and those



that have a location quotient less than one (i.e., non-mining counties). We then compare and contrast the socioeconomic and health measure across the two groups.

As reported in Map 2a we can see that there are several “mining dependent” counties given our simple threshold of a

location quotient greater than one scattered across the U.S. including several counties located in Wisconsin. But as with the mining employment per capita metric the counties with the largest location quotients are located in the mountain west, particularly Nevada, and the coal belt of Appalachia. There are 450 nonmetropolitan or 22.4 percent of all counties that have a location quotient greater than one or classified as “mining dependent”. There are 108 counties (5.4 percent) that have a location quotient greater than ten. While there is no research based critical threshold of a location quotient where a county truly becomes “dependent” upon mining, it is generally accepted that a location quotient bigger than five is considered “large” and defines a dependency level. There are a small handful of counties that have mining location quotients greater than 100, which is enormous by any standard, and are the

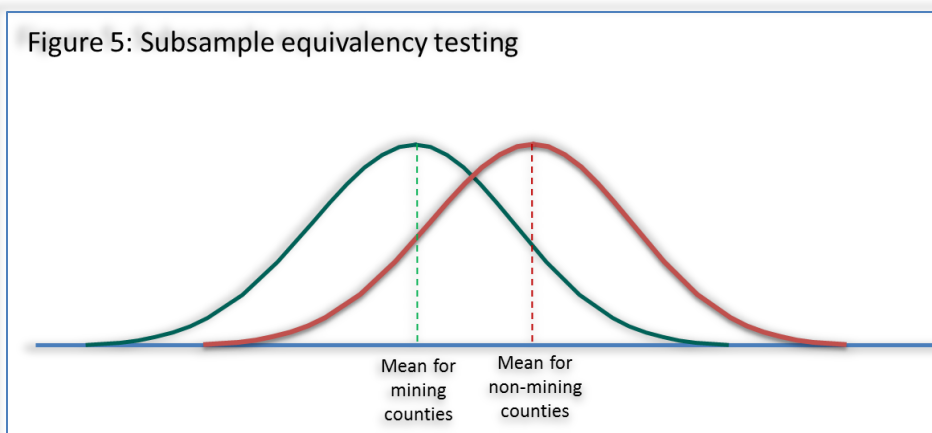


coal region of Kentucky and other parts of Appalachia, Nevada, Arizona, parts of Colorado, Montana and Wyoming.

If we again apply the statistical spatial clustering tool to the location quotient data, we can again see spatial clusters or “hot spots” of mining in the Appalachia coal

belt, Nevada and a band from Arizona north to the Canadian border (Map 2b). The overlap between the spatial clusters identified by the number of mining jobs per capita (Map 1b) and those identified with the location quotient (Map 2b) is substantial. Again, while there are mining operations scattered across the U.S., the concentration of non-oil and gas mining is located in specific parts of the U.S.

As describe above we use the location quotient to group U.S. nonmetropolitan counties into two groups, those with a location quotient greater than one and those with a location quotient less than one. We then compare and contrast the socioeconomic and health measure across the two groups. Suppose that we plot the data for one of the metrics of community well-being for each of the two groups as in Figure 5. The idea is to see if the means across the two samples are the same (or more correctly, the difference between the two means is zero). If the two means are indeed statistically different then we can infer that counties that are “mining dependent” are different from non-mining counties. If the two



distributions are statistically the same, then there is no difference between “mining dependent” and non-mining counties. The subsample equivalency tests include two tests for central

tendency and three non-parametric tests of distribution. The central tendency tests are the ANOVA F-test for mean equivalency and the non-parametric median test of central tendency. The van der Waerden, Savage and Kruskal-Wallis are non-parametric tests that compare the distribution of the measures of economic performance across the sub-samples. In essence, the last three tests look not at the means but the distribution or shape of the curves in Figure 5.<sup>4</sup>

The analysis for the socioeconomic data is provided in Table 3 and the health data results are provided in Table 4. Here we find that the poverty rate, both the overall rate for individuals tends to be higher in mining dependent counties (15.45) when compared to other nonmetropolitan counties (14.51) and the test statistics, specifically the F statistic and median test, strongly suggest that this difference is statistically significant. A similar observation can be made for the child poverty rate: mining counties have a higher rate (21.71) than other nonmetropolitan counties (20.24) and again the test statistics confirm the significance of the differences. This is in contrast to the findings using mining employment per capita outline in Table 1. The mean level of income inequality, however, appears to be the same across the two groups. Unemployment rates tend to be higher in mining counties (6.04) than other nonmetropolitan counties (5.76) with the difference being statistically significant.

We also find that there is weak evidence that the violent crime rate might be higher in non-mining nonmetropolitan counties (201.07) than mining counties (181.53). The evidence is weak because the F test comparing the means of the distributions of the two groups is not significant suggesting no measurable difference, but the median test suggests that the medians are different. There is a strong statistically significant difference between the two groups in terms of property crime. Here the property crime rate is lower in mining counties (1538.12) than in other nonmetropolitan counties (1863.30). This is again in contrast to the findings using mining employment per capita outline in Table 1. We also find that the levels of education tend to be higher in non-mining metro counties when compared to mining dependent counties as defined by the location quotient.

Now consider the rest of the subsample equivalency testing using metrics of community health (Table 4). First, it appears that there is no difference in the percent of children under the age of 18 that are without health insurance. While the mean for mining counties (12.47) appears to be slightly higher than

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<sup>4</sup> The sub-sample equivalency tests include two tests for central tendency and three non-parametric tests of distribution. The central tendency tests are the ANOVA F-test for mean equivalency and the non-parametric median test of central tendency. The van der Waerden, Savage and Kruskal-Wallis are non-parametric tests that compare the distribution of the measures of economic performance across the sub-samples. The test of median equivalency tests the null hypothesis that the medians of the populations from which the samples are drawn are identical. The median test categorizes all scores as above or below the median and then tests for differences among the sub-samples. The median test is considered elementary, but because there are so few assumptions a statistically significant result is very convincing. The van der Waerden test is a non-parametric test for the homogeneity of samples based on the rank statistic where the rank scores are the quantiles of a standard normal distribution. The Savage test is similar, but is built on an exponential distribution. Kruskal-Wallis is similar to the Wilcoxon test but for several sub-samples and does not assume a normal distribution.

Table 3. Sub-Sample Equivalency: Mining Location Quotient Greater Than One, Economics

	Mining	NonMetro	F Statistic	Kruskal-Wallis (Chi-Square)	Median (Chi-Square)	Van der Waerden (Chi-Square)	Savage (Chi-Square)
Poverty Rate	15.45	14.51	<b>8.35</b>	<b>12.14</b>	<b>8.91</b>	<b>11.23</b>	<b>5.38</b>
Children in Poverty Rate	21.71	20.24	<b>10.21</b>	<b>13.62</b>	<b>15.89</b>	<b>11.71</b>	<b>6.10</b>
Income Inequality (GINI Coefficient)	43.50	43.58	0.13	0.00	0.22	0.12	0.35
Unemployment Rate	6.04	5.76	<b>5.88</b>	<b>8.62</b>	<b>5.04</b>	<b>8.45</b>	<b>3.31</b>
Violent Crime Rate	181.53	201.07	2.58	<b>3.94</b>	<b>3.88</b>	<b>4.00</b>	2.45
Property Crime Rate	1538.12	1863.30	<b>15.53</b>	<b>12.42</b>	<b>13.69</b>	<b>13.47</b>	<b>16.15</b>
Persons over 25 with a High School Degree (%)	74.44	76.26	<b>10.84</b>	<b>11.63</b>	<b>7.35</b>	<b>11.61</b>	<b>8.69</b>
Persons over 25 with a Bachelor Degree (%)	12.92	14.66	<b>24.78</b>	<b>35.25</b>	<b>22.55</b>	<b>36.92</b>	<b>23.39</b>

Bold test statistic significant at 90%, bold and italics test significant at 95%.

Table 4. Sub-Sample Equivalency: Mining Location Quotient Greater Than One, Health

	Mining	NonMetro	F Statistic	Kruskal-Wallis (Chi-Square)	Median (Chi-Square)	Van der Waerden (Chi-Square)	Savage (Chi-Square)
Under 18 Without Health Insurance (%)	12.47	12.13	0.91	0.59	0.14	0.85	0.91
Premature death (Years of Potential Life Lost)	9,358.61	8,640.38	<b>19.89</b>	<b>23.39</b>	<b>16.38</b>	<b>23.33</b>	<b>16.87</b>
Poor or fair health (%)	19.56	17.22	<b>28.50</b>	<b>16.85</b>	<b>7.93</b>	<b>22.94</b>	<b>35.14</b>
Poor physical health days	4.34	3.79	<b>47.98</b>	<b>30.21</b>	<b>12.29</b>	<b>37.88</b>	<b>51.28</b>
Poor mental health days	3.75	3.40	<b>22.12</b>	<b>16.99</b>	<b>12.25</b>	<b>20.02</b>	<b>22.52</b>
Low birthweight (%)	8.38	7.98	<b>9.05</b>	<b>19.50</b>	<b>22.03</b>	<b>14.99</b>	<b>3.91</b>
Adult smoking (%)	23.54	22.55	<b>4.78</b>	<b>3.45</b>	<b>3.25</b>	<b>4.54</b>	<b>7.12</b>
Adult obesity (%)	28.39	28.57	0.71	0.00	0.23	0.12	0.28
Binge drinking (%)	12.20	13.31	<b>8.14</b>	<b>9.06</b>	<b>5.07</b>	<b>7.94</b>	<b>3.55</b>
Chlamydia rate (per 100k)	205.45	238.86	<b>4.67</b>	<b>7.18</b>	<b>6.70</b>	<b>5.25</b>	<b>6.11</b>
Teen Birth Rate	50.81	51.33	0.14	0.00	0.70	0.01	2.14
Single-Parent Households (%)	8.27	8.56	2.65	0.93	0.01	1.33	<b>3.58</b>
Ozone Days	0.84	0.96	0.43	1.56	1.85	1.32	1.00

Bold test statistic significant at 90%, bold and italics test significant at 95%.

other nonmetropolitan counties (12.13) the difference is not statistically different from zero. We do find that mining counties have higher average rates of premature death (years of potential life lost), percent of persons in poor or fair health, poor physical health days, poor mental health days, percent of births that are low birth weight, and percent of adults that smoke. There is no difference between mining and other nonmetropolitan counties in terms of adult obesity but it appears that the rates of binge drinking and chlamydia rates are lower in mining counties. We find no differences between the two groupings of counties for teen birth rates, single-parent households, or ozone days.

**General conclusions and discussion** If we compare the results using number of mining jobs per capita and the subsample equivalency testing based on the location quotient, we find both consistency and inconsistency. In terms of consistent results, we generally find that community health tends to be lower in mining counties along with overall education levels. But mining counties perform better in some health metrics such as chlamydia rates. We also find that unemployment tends to be higher with increased mining activity and there are no differences in violent crime rates. We do find inconsistencies with respect to property crime rates and some of the health metrics including low birth weight. More generally, the inconsistent finding hinge on levels of statistical significance. Using mining employment per capita we find some relationships statistically significant, but when using the group comparisons based on the location quotient those findings are statistically insignificant. For example, we found higher number of mining jobs per capita is associated with lower levels of income inequality but no differences using the location quotient approach.

The apparent inconsistencies in our findings for the socioeconomic well-being metrics across our two measures of mining activity allow us to draw a couple conclusions. *First, one must guard against making blanket generalizations about the impact of mining on the local community. In many ways mining can provide well-paying jobs leading to lower levels of poverty. But on the other hand, mining activity appears to be associated with poorer overall health levels within the community. Second, how one measures mining activity can have a significant impact on the results. Consistent with the findings of Weber, Castle and Shriver (1987) how one thinks about and defines mining can alter the results. This latter observation points to a third conclusion, frac sand mining in Wisconsin will develop differently from other types of mining. This is not to say that local communities across Wisconsin cannot learn from the experiences of other mining areas, but rather each community is unique.*

What this analysis cannot help us understand is the influence of mining over time. The analysis presented in this section represents a simple snap-shot in time, or what is referred to as a cross-sectional analysis. One of the major justifications for promoting mining as an economic policy is its potential impact on economic growth. We have seen that from an economic development perspective, specifically a broad sense of community well-being, there are both positive (e.g., lower poverty) and negative (e.g., poorer levels of health across several measures) impacts resulting from mining. But these do not speak to economic growth, or change over time. We now address issues of economic growth.



## Simple growth models

One of the major rationales for promoting the mining industry, specifically frac sand mining, is the positive impact that it will have on economic growth. As we have outlined in our review of the literature, there tends to be a cycle of economic “boom-busts” intermixed with levels of instability or flickering, associated with the mining industry. Mines by definition have a finite life-frame. The resources being mined will be exhausted at some point in time and the operations will close. The policy debate often hinges on safeguarding communities to minimize the negative impacts of the “boom” and build on the positive aspects while also building institutional and economic resources to minimize the “bust” when the resources are fully extracted.

Before we can have such a discussion, however, it is important to assess the actual impact mining has on the economic growth process. In this section of the report we outline a standard model of economic growth along with the results of a simple set of statistically estimated growth models using U.S. nonmetropolitan county data. We look at how conditions in 2000 impact or influence the levels of economic growth between 2000 and 2007. We elected to end the study period in 2007 to remove the effects of the “Great Recession”. We use three groupings of nonmetropolitan counties in our analysis: (1) all nonmetropolitan counties, (2) all nonmetropolitan counties that are adjacent or next to metropolitan counties, and (3) all nonmetropolitan counties that are non-adjacent to metropolitan counties, or remote counties. We use these subgroupings of counties for two reasons. First, there is significant evidence that proximity to urban (i.e., metro) areas is a major driver of nonmetropolitan growth. Second, the vast majority of counties in Wisconsin that are being impacted by frac sand mining are non-adjacent or remote rural counties. Thus to aggregate all nonmetropolitan counties together might lead to inaccurate insights for most Wisconsin counties.

To explore the role of mining activity on nonmetropolitan economic growth we use a simple three equation model of regional economies:<sup>5</sup>

$$P^* = f(E^*, I^* | \Omega^P) \quad (1)$$

$$E^* = g(P^*, I^* | \Omega^E) \quad (2)$$

$$I^* = g(P^*, E^* | \Omega^I) \quad (3)$$

Here  $P^*$  represents some equilibrium level of *population* growth,  $E^*$  represents the equilibrium level of *employment* growth and  $I^*$  captures *income*. The idea is if people follow jobs, or do jobs follow people, and how does income (potential earnings) impact that pattern? Here all three (jobs, population and income) are all determined jointly or at the same time. There are also other community (county) characteristics ( $\Omega$ ) that influence those patterns. Examples of these other characteristics for rural counties include proximity to urban areas, natural amenities, and a range of socioeconomic characteristics such as poverty rates, age profiles and educational attainment.

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<sup>5</sup> This modeling approach was first introduced by Carlino and Mills (1987) and expanded to this version by Deller, et al. (2001).

We can express this theoretical framework as:

$$\Delta P = \alpha_{0p} + \beta_{1p}P_{t-1} + \beta_{2p}E_{t-1} + \beta_{3p}I_{t-1} + \gamma_{1p}\Delta E + \gamma_{2p}\Delta I + \sum \delta_{ip}\Omega^p \quad (4)$$

$$\Delta E = \alpha_{0E} + \beta_{1E}P_{t-1} + \beta_{2E}E_{t-1} + \beta_{3E}I_{t-1} + \gamma_{1E}\Delta P + \gamma_{2E}\Delta I + \sum \delta_{iE}\Omega^E \quad (5)$$

$$\Delta I = \alpha_{0I} + \beta_{1I}P_{t-1} + \beta_{2I}E_{t-1} + \beta_{3I}I_{t-1} + \gamma_{1I}\Delta E + \gamma_{2I}\Delta P + \sum \delta_{iI}\Omega^I \quad (6)$$

which is simply an empirical representation of the theoretical framework which we can use statistical methods to estimate. Here the change (i.e., growth) in population ( $\Delta P$ ) is dependent upon population at the beginning of the period ( $P_{t-1}$ ), employment at the beginning of the period, income (measured as per capita income) at the beginning of the period, and changes in employment ( $\Delta E$ ) and income ( $\Delta I$ ) as well as a set of what we refer to as control variables ( $\Omega^P$ ). The same applies to the employment and income equations.<sup>6</sup>

Our set of control variables include:

- Percent of the Population Over Age 65 2000
- Ethnic Diversity Index 2000
- Percent of the Population Over Age 25 with a Bachelor Degree 2000
- Percent of the Population Foreign Born 2000
- Percent of the Population Speaks A Language Other than English at Home 2000
- Percent of the Population Living in Same Residence in 2000 as in 1995
- Poverty Rate 2000
- **Mining Employment to Population Ratio**
- **Mining Employment as a Share of Total Employment**

These variables are selected based on our previous research and are intended to capture some of the socioeconomic characteristics of the community (county). For example, the larger the share of the population that is over age 65 speaks to the supply of labor as does the percent of the population with a bachelor's degree. These also help capture the attitudes toward growth itself. For example, older persons may be more inclined to prefer a slower growth rate than a younger population who are looking for employment opportunities. The poverty rate also indicates the supply of labor and the attitudes toward economic growth. The ethnic diversity index (higher values of the index are reflective of a more homogenous population, a lower value a more mixed ethnic profile), percent of the population foreign born and English language measures are intended to reflect the growing diversity of many rural communities. Housing stability (same residence in 2000 as in 1995) signifies the stability of the community and is a very simple proxy of the social capital within the community.

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<sup>6</sup> To further simplify the model researchers often move to what is referred to as the "reduced" form. For our case, that would involve removing the change variables ( $\Delta E$ ,  $\Delta P$  and  $\Delta I$ ) from the right-hand-side of the models and equivalently define the set of control variables across all three models (i.e.,  $\Omega^P = \Omega^E = \Omega^I$ ).

The two measures that are of particular interest to this research are the two measures of mining activity. Consistent with the more descriptive analysis presented earlier in this study we use two metrics that tend to be highly correlated (a simple correlation coefficient is 0.711, see Appendix Figure A): number of mining jobs per capita and share of employment in mining. The central hypothesis is that if mining has a positive impact on economic growth, then we should see a positive and statistically significant coefficient associated with both of these metrics on each of our growth equations.

Consider first the results for the models where we include all nonmetropolitan counties in the sample (Table 5). Before turning to the two variables of interest (mining employment) review the results of the other variables in the model.

- Larger counties measured by population tend to have faster rates of growth in population and employment, but weakly (statistically) slower rates of growth in income.
- Larger counties measured by employment have slower rates of population and employment growth, and employment size places no role in explaining income growth.
- Richer counties measured by per capita income tend to have slower population and employment growth rates as well as slower growth rates in per capita income. This latter result is sometimes referred to as evidence of “convergence”: poorer counties are catching up to or converging to richer counties.
- An older population has a negative impact on population and employment growth, but a positive impact on income growth.
- A more homogenous ethnic make-up (i.e., less ethnic diversity) has no influence on population growth, and a positive impact on employment and income.
- A more highly educated population has no influence on population growth, but has a positive impact on employment and income growth.
- Percent of the population foreign born has no influence on population, employment or income growth.
- Percent of the population that speaks a language other than English at home has a weak (statistically) negative impact on population growth, but a positive impact on employment and income growth.
- Residential stability has a negative impact on population and employment growth, and a positive impact on income growth.
- Higher poverty has a negative impact on population and employment growth and does not influence income growth.

Now consider the two variables of central interest to this analysis, the two mining activity metrics. With respect to population growth, the mining employment per capita metric has a negative impact on population growth. Likewise, the share of employment in mining has a negative coefficient, albeit with weak statistical confidence in the latter result. **Hence, we have weak evidence that counties more heavily dependent on mining for employment will tend to have a slower population growth rate. There is more consistent evidence that mining has a positive impact on employment and income growth rates.** But, if we return to Figures 1 and 2, the period that studied here (2000 to 2007) is one of

growth in the larger mining industry. Our growth modeling results may be capturing the overall upward trend in the mining industry.

Now consider the subset of nonmetropolitan counties that are adjacent to urban or metropolitan counties (Table 6). For both metrics of mining activity, it appears that from a statistical perspective mining has no influence on population, employment or income growth rates. Although the coefficients in the population and employment growth models are negative, suggesting that mining is associated with lower levels of growth, the results are weak statistically leading us to conclude that for rural counties that are adjacent to urban areas, mining does not play a significant role in helping us understand the economic growth process.

Now consider the results for those *remote rural* (nonmetropolitan) counties (Table 7). For most Wisconsin counties being impacted by frac sand mines, these results are the most appropriate to draw upon. Using mining employment per capita (or mining employment to population ratio) we find that higher dependency on mining has a negative impact on population growth patterns. But at the same time, higher dependency on mining using this metric is associated with higher rates of employment growth as well as higher rates of income (per capita income) growth. Using the mining as a share of total employment we again find a negative impact on population growth rates, but the statistical reliability of this result is weak at best. Strictly speaking it appears that ***a higher share of employment in mining does not influence population growth rates in these remote rural areas. We do find evidence that higher levels of dependency on mining for jobs are associated with employment and income growth.***

These results suggest that mining activity, measured by employment, does influence the growth rate of nonmetropolitan U.S. counties. We find that higher levels of mining employment tends to have a weak dampening effect on population growth rates, but a strong positive impact on employment and income growth rates. In addition, these findings tend to hold for remote rural counties, but not necessarily for rural counties adjacent to urban areas. Thus, depending on the metric of economic growth used, mining activities can have a weak negative impact (population) or a positive impact (employment, income).

## **Conclusions and discussion**

This study has attempted to shed some light on the role of mining activities on local community well-being. For the national descriptive analysis we use all mining activity. But for our statistical analysis we define mining as all types of mining except for oil and gas extraction. We remove these two types of mining activity because our central interest is how frac sand mining may, or may not, impact Wisconsin communities. The production processes in oil and gas extraction is so fundamentally different from sand mining that including it would introduce “noise” into the analysis. We also focus only on nonmetropolitan (rural) communities (counties) because these are most like the communities to be affected by sand mining in Wisconsin. We look at a series of community well-being metrics including socioeconomic characteristics, health, and economic growth.

While our results are somewhat sensitive to how one measures economic dependency on mining (mining employment per capita, mining employment to population ratio, or the share of county employment in mining to the national average), there is sufficient consistency to draw important conclusions. First, higher dependency on mining for employment tends to be associated with lower poverty rates and faster rates of growth in employment and income. Second, higher dependency on mining for employment tends to be associated with lower levels of some measures of community health and weakly associated with slower population growth.

These conclusions suggest that higher levels of mining may have positive economic impacts (lower poverty and higher rates of employment and income growth), but may come at the expense of poorer health levels.

Table 5. Growth Models All Nonmetro Counties

	Population Growth	Employment Growth	Per Capita Income Growth
Intercept	0.4044 (0.0001)	26.4485 (0.0001)	0.0971 (0.0898)
Population 2000	0.0232 (0.0001)	3.8888 (0.0001)	-0.0074 (0.0770)
Employment 2000	-0.0327 (0.0001)	-7.2893 (0.0001)	-0.0064 (0.6599)
Per Capita Income 2000	-0.0091 (0.0721)	-2.5955 (0.0135)	-0.0821 (0.0006)
Percent of the Population Over Age 65	-0.5292 (0.0001)	-34.9067 (0.0007)	0.6563 (0.0001)
Ethnic Diversity Index	0.0063 (0.5622)	3.2680 (0.0635)	0.0593 (0.0017)
Percent of the Population Over Age 25 with a Bachelor Degree 2000	-0.0272 (0.5080)	58.0293 (0.0001)	0.9697 (0.0001)
Percent of the Population Foreign Born 2000	0.0927 (0.1992)	6.2929 (0.5506)	-0.0282 (0.8542)
Percent of the Population Speaks A Language Other than English at Home 2000	-0.0370 (0.0808)	15.9982 (0.0001)	0.3170 (0.0001)
Percent of the Population Living in Same Residence in 2000 as in 1995	-0.4677 (0.0001)	-30.7977 (0.0001)	0.3331 (0.0001)
Poverty Rate 2000	-0.2239 (0.0001)	-24.0536 (0.0006)	-0.0179 (0.8857)
Mining Employment to Population Ratio	-0.0057 (0.0152)	1.7278 (0.0001)	0.0229 (0.0239)
Mining Employment as a Share of Total Employment	— (0.1850)	— (0.0691)	— (0.0070)
R <sup>2</sup>	0.3890	0.1829	0.2043
F statistic	116.93 (0.0001)	41.76 (0.0001)	47.75 (0.0001)

Marginal significance in parentheses.

Table 6. Growth Models Nonmetro Adjacent Counties

	Population Growth	Employment Growth	Per Capita Income Growth
Intercept	0.3998 (0.0001)	24.4212 (0.0001)	0.1853 (0.0043)
Population 2000	0.0269 (0.0001)	4.2960 (0.0001)	-0.0073 (0.1541)
Employment 2000	-0.0467 (0.0001)	-8.5088 (0.0001)	0.0030 (0.6987)
Per Capita Income 2000	0.0087 (0.5059)	-0.5970 (0.7736)	-0.1460 (0.0001)
Percent of the Population Over Age 65	-0.4325 (0.0001)	-9.0523 (0.5777)	1.0473 (0.0001)
Ethnic Diversity Index	0.0076 (0.6297)	4.1212 (0.0862)	0.1176 (0.0001)
Percent of the Population Over Age 25 with a Bachelor Degree 2000	-0.0250 (0.7116)	50.2890 (0.0001)	0.9307 (0.0001)
Percent of the Population Foreign Born 2000	0.2531 (0.0173)	18.6350 (0.1486)	-0.0058 (0.9789)
Percent of the Population Speaks A Language Other than English at Home 2000	-0.0558 (0.0773)	17.9726 (0.0005)	0.4805 (0.0001)
Percent of the Population Living in Same Residence in 2000 as in 1995	-0.5259 (0.0001)	-40.6216 (0.0001)	0.3175 (0.0023)
Poverty Rate 2000	-0.2234 (0.0050)	-15.6253 (0.2008)	-0.3122 (0.0779)
Mining Employment to Population Ratio	-0.0258 (0.3583)	-1.7156 (0.6306)	0.1334 (0.1098)
Mining Employment as a Share of Total Employment	— (0.6054)	— (0.3865)	— (0.1473)
R <sup>2</sup>	0.3342	0.1784	0.3001
F statistic	48.51 (0.0001)	21.55 (0.0001)	41.57 (0.0001)

Marginal significance in parentheses.

Table 7. Growth Models Nonmetro Not-Adjacent Counties

	Population Growth	Employment Growth	Per Capita Income Growth
Intercept	0.3276 (0.0001)	20.9079 (0.0003)	19.9805 (0.0005)
Population 2000	0.0150 (0.0062)	2.6353 (0.0013)	0.1557 (0.0654)
Employment 2000	-0.0119 (0.1904)	-4.6696 (0.0012)	-0.0298 (0.0094)
Per Capita Income 2000	-0.0127 (0.0187)	-3.2734 (0.0035)	0.0237 (0.2072)
Percent of the Population Over Age 65 2000	-0.5975 (0.0001)	-59.4042 (0.0001)	-0.0684 (0.0119)
Ethnic Diversity Index 2000	-0.0111 (0.4540)	0.6594 (0.8013)	0.3117 (0.0622)
Percent of the Population Over Age 25 with a Bachelor Degree 2000	0.0270 (0.6071)	66.6074 (0.0001)	0.9162 (0.0001)
Percent of the Population Foreign Born 2000	-0.0862 (0.3283)	-12.1358 (0.4522)	-0.1149 (0.6135)
Percent of the Population Speaks A Language Other than English at Home 2000	-0.0214 (0.4438)	13.8382 (0.0165)	0.1851 (0.0285)
Percent of the Population Living in Same Residence in 2000 as in 1995	-0.3529 (0.0001)	-13.8276 (0.0364)	0.3446 (0.0018)
Poverty Rate 2000	-0.1561 (0.0061)	-27.0966 (0.0039)	0.0258 (0.8743)
Mining Employment to Population Ratio	-0.0037 (0.0451)	1.8481 (0.0001)	0.0163 (0.0135)
Mining Employment as a Share of Total Employment	— (0.1125)	— (0.0001)	— (0.0015)
$\bar{R}^2$	0.4017	0.1921	0.1262
F statistic	59.65 (0.0001)	21.77 (0.0001)	13.62 (0.0001)

Marginal significance in parentheses.



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