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Mining and Community Economic Growth

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Abstract: The rapid expansion of oil and gas extraction in large parts of the Marcellus fields in the Appalachian Basin and the Bakken fields in the Williston Basin of the Dakotas and Montana has reignited debate over the role of natural resource extraction as a rural economic growth strategy. While the popular media has focused on hydraulic fracturing and natural gas and oil production, there has been significant interest in silicon sand mining in western Wisconsin and southeastern Minnesota. This "frack sand" is used in oil and gas hydraulic fracturing activity. In this study we explore the relationship between non-oil and gas mining (NAICS 212) activities and economic growth for nonmetropolitan U.S. counties for the period 2000 to 2007. We find robust results suggesting that non-oil and gas mining is associated with lower population growth, and a positive impact on per capita income, but has no impact on employment growth.

Keywords: rural development, mining, economic growth

JEL Codes: R11, Q34

1. INTRODUCTION

As the national economy struggles to recover from the Great Recession, the high price of oil and the increasingly large potential for natural gas consumption has created economic opportunities for rural communities. The process of hydraulic fracturing, or "fracking," used to remove energy resources from rock formations, has created mining booms in areas of the western Appalachian Mountains (the Marcellus fields in the Appalachian Basin) and parts of North Dakota and Montana (the Bakken fields in the Williston Basin). One element of fracking is the requirement of proppants, which are forced under high pressures into a shale gas well along with large quantities of water and industrial fluids to stimulate gas production once the rocks begin fracturing. Proppants are used to "prop" open the underground cracks from which natural gas or oil is extracted. Typical proppants include sand crystals, such as quartz/silica or sandstone because of the unique size and shapes, which are found almost exclusively in western Wisconsin and southeastern Minnesota.

Given the depth 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 proposed mines are likely to be located in more-rural and low-income areas where the job-generating potential has overridden environmental concerns. The transition from extractive-based industries (e.g., mining and forestry) to non-extractive-based activities (e.g., recreation, tourism and amenity-driven migration) raised tension in many of these rural communities

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(Marcouiller, 1997; 1998; English, Marcouiller, and Cordell, 2000; Marcouiller, Clendenning, and Kedzior, 2002; Barieri and Valdivia, 2010; Ward, 2011). Power and Barrett (2001) eloquently argue that this transition from extractive to non-extractive industries has not only changed the economic base of many rural communities but also their self-identity. As such, the draw to return to more traditional extractive-based industries is strong in many communities. The immediacy of mining jobs, therefore, has dominated the thoughts and actions of many local officials while other factors, such as the impact on non-extractive industries that thrive on the natural amenities, have been largely pushed aside.

The viability of mining as an economic growth and development strategy has been widely challenged under the guise of the "resource curse" (Humphreys, Sachs, and Stiglitz, 2007; James and Aadland, 2011). As noted by Bridge (2008), 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 (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, if this same general conclusion applies to the rural U.S. The handful of studies that examine the resource curse for the United States finds mixed and at times contradictory results (see for example Bender et al., 1985; Weber, Castle, and Shriver, 1988; Nord and Luloff, 1993; Mills, 1995; Papyrakis and Gerlagh, 2007; James and Aadland, 2011). Results vary by the type of mining, the time-period, and the metric of economic growth examined.

This study explores the role of non-oil and gas extractive mining on the economic growth of nonmetropolitan U.S. counties from 2000 to 2007. We use an expanded version of the classic Carlino and Mills (1987) regional adjustment growth model. We focus on mining such as sand and mineral mining including coal, using both employment to population ratio and share of total employment in mining along with spatial lag and spatial error estimators to explore the robustness of the results. Beyond these brief introductory comments the study is composed of five sections including a review of the literature, an outline of the theoretical framework, empirical specification and estimators, the empirical results themselves, and a summary of the study's key findings. Particular attention is paid to the implications on community economic growth policies.

2. LITERATURE REVIEW

There are only a handful of peer reviewed studies that examine how mining operations influence the economies of communities. 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 the "grey" literature.[1] 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

[1] 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.

Weinstein and Partridge (2011) have noted, recent studies funded by extractive industries tend to overstate employment growth, while ignoring labor displacement from other sectors.

The mining literature that focuses on developing countries, generally 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, policymakers strive to achieve their comparative advantage as outlined in international trade theory (Bridge, 2008). In the rudimentary framework of export base theory, which still forms the backbone of much of the thinking about community economic development strategies, the region's endowment of natural resources defines their comparative advantage and as a consequence, their economic growth strategies (Kilkenny and Partridge, 2009). In the case of subsurface mineral resources, an analogy is often made with buried treasure and technology providing the key to opening the treasure chest (Bomsel, 1990). As noted by Gunton and Day (2003) as well as Bridge (2008), the external sources of investment for mining projects create a spread effect that 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.

Much of the research that examines mining within developing nations concludes that very little of the economic benefits are retained in the local economy because of the ownership structure of mining firms and lax environmental or labor safety standards. The economic historian Innis (1956) studied the case of Canadian specialization around resource extraction and found that such activities did not drive economic diversification but rather a form of dependency on an unstable industry. Bridge (2008) noted that the majority of the resource curse literature finds robust economic growth associated with development from resource extraction to be a rarity as opposed to a general rule (Ross 1999; Sachs and Warner 1999; Watts 2005; Rosser 2006).

It is not clear if the resource curse that dominates the international development literature is directly transferable to many parts of the United States. First, the institutional rules that govern extractive industries in the United States are far more rigid and conducive to minimizing many of the negative externalities associated with mining. Mehlum, Moene, and Torvik (2006) argued that the quality of institutions is a large determinant of the economic effects of resource extraction, thus begging the question of how pertinent the resource curse may be for the United States. For instance, labor laws prohibiting the exploitation of workers (often at the heart of causal factors for the resource curse) are far more pervasive in the U.S. setting. Second, many developing countries lack the institutional structure to capture the economic opportunities created by extractive industries. As shown by Wagner and Deller (1998), actively pursuing short-run growth strategies within an overarching long-run goal can lead to simultaneous growth and stability. That is, localities that "settle" on being dependent upon a single industry, such as mining, and do not seek to diversify from that industry, expose the local economy to unnecessary risks. Developing countries with limited institutional capacities often suffer from a severely myopic perspective because of such dominance, thus failing to maintain long-run focus.

There are a few studies focused on the resource curse within the United States. Many researchers treat mining as part of the more generic "extractive industries" category, aggregating industries such as fisheries, forestry, agricultural activities, and mining. Papyrakis and Gerlagh

(2007), using state-level data, noted that resource abundance tends to decrease investment and the quality of schools and increase overall corruption within policing authorities, thereby stunting state-level growth. James and Aadland (2011) used U.S. county-level data and found that resource-dependent counties tend to cultivate anemic growth relative to non-resource-dependent counties. These studies, however, ignore the specific characteristics of individual extractive industries. Therefore, direct conclusions associated with mining should be taken lightly.

One of the first studies to provide a comprehensive analysis on the impact of mining on community economic development was undertaken by the USDA's Economic Research Service. This study compared "mining-dependent" counties (those where 20 percent or more of total labor and proprietor income came from mining) with 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. Nord and Luloff (1993) extended these ideas by decomposing mining into three types (coal, petroleum and "other") and examined three regions of the U.S. including the South, Great Lakes, and West. Using the 1980 Census Nord and Luloff generally confirmed the results of Bender et al. (1985), but post-1980 the economic implications of mining deteriorated across all three types of mining and all three regions. For example, by 1990 all mining-dependent counties experienced faster growth rates in poverty than other nonmetropolitan counties. When decomposing mining into its material-specific activities, Weber, Castle, and Shriver (1988) found that U.S. counties with energy-related mining experienced growth in employment and earnings during the mining boom years 1973-1985; however, counties with metal mining experienced a decline in these measures during those same years. These authors found excessively high rates of unemployment associated with extractive industries relative to other sectors.

Other studies that focus on the boom-bust phenomenon associated with mining activities tend to find that the negative effects on employment during the bust period outweigh any positive outcomes of the boom period. In a study that uses data from the coal boom and bust of the 1970s and 1980s, Black, McKinnish, and Sanders (2005) noted that the negative spillovers of the coal bust were considerably larger than positive spillovers observed during the boom years. The authors studied the coal producing Appalachian regions by separating counties deemed mining-dependent whose occupants earned more than 10 percent of total income from coal mining activities forming a treatment group. Using employment differentials, 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. Thus, the local labor market was in worse condition after mining operations stopped.

Lockie et al. (2009) conducted a longitudinal study of the Coppabella coal mine in Queensland, Australia and found that 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 2.35 jobs were created for every million dollars of gas produced thus generating an increase in employment growth of roughly 1.5 percent. In contrast Marchand (2012) found that total employment grew 6.5 percent for the 1996 to 2006 oil and gas boom in Western Canada. These positive conclusions, however, are reflective of "boom" years. Marchand noted consistent negative effects during the "bust" period. During the bust period, per capita income declined, with particularly negative impacts on the construction, retail and service sectors. Slack and Jensen (2004) found that, relative to other extractive industries, mining labor is less likely to be underemployed. When compared to the service sector, workers employed in mining are roughly 20 percent less likely to be underemployed. These studies suggest that the employment effects of mining tend to be positive during the boom years; however, the decline in bust periods outweighs previous positive effects. Also, the effects of mining on local economies are seemingly sensitive to the type of metric used to measure employment.

A common observation in the literature is the simultaneous increase in poverty levels in mining-intensive areas with an accompanying rise in per capita income (e.g., Gramling and Brabant, 1986). In essence, there is widening income inequality. Nord (1994) suggested that those employed in extractive industries are able to maintain low wage growth because intra-industry management positions are often concentrated elsewhere. Mills (1995) found that earnings per worker were higher in the mining sector relative to other sectors, suggesting that mines may pay higher wages, but those higher wages do not translate into lower poverty rates. Marchand (2012) noted substantial increases in earnings per worker and decreased levels of poverty during the oil and gas boom in Western Canada. Michaels (2011) suggested that a plot of per capita income over time for resource abundant communities exhibits an inverted-U shape. The author studied oil abundant counties within the United States and found a consistent 5-6 percent increase in per capita income relative to other counties in 1989. Such effects on income are not as clear for non-oil and gas mining activities.

Some authors have questioned whether the influx of labor to work in developing mines is beneficial for the local economy. Cushing (1999) studied the Appalachian region of the United States and found that many of the low skilled jobs in mines attract a labor force that may limit future economic growth and contribute to higher poverty rates. Lockie et al. (2009) found increased anti-social behavior, such as traffic-related accidents and increases in criminal activity, a few years after the boom in commodity prices. A common phenomenon is the in-migration of lower skilled workers seeking, but failing to find, mining employment. Bradbury (1984) suggested that the mobility of workers is often overlooked in studies of the effects of mining on local communities.

Sociologists have tended to highlight the interplay of instability in 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 suggested 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 mining activity ceases and when prices return to higher levels mining activity returns. This inherent instability or flickering effect stunts local economic growth. Because of uncertainty associated with this flickering effect, other non-basic businesses, such as consumer services and retail, do not grow in response to the mining operations.

Wilson (2004), however, suggested that Freudenburg's theory should be modified to include specific characteristics of the commodity and local economy, before accepting the link between volatile world prices and instability or flickering in the local economy. Furthermore, Stedman, Parkins, and Beckley (2004) studied resource dependence in rural Canada and noted the need for models to incorporate regional specifics when attempting to quantify the effects of mining or other extractive activities. Variables under consideration included the size of the mining operation, the remoteness of the mine, or the presence of other non-mine related economic activities. Such efforts reflect the heterogeneity in the impact of mining activities.

In an extensive review of the peer-reviewed qualitative and quantitative U.S. specific mining studies, Freudenburg and Wilson (2002) noted that regional variation was indeed a pervasive theme. In particular, studies examining mines in the Western region of the United States typically reached more favorable conclusions than those focusing on the rest of the country. The authors also found that the majority of the reviewed material indicates adverse economic effects in mining communities. Interestingly, Freudenberg and Gramling (1994) suggested 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. This goes back to the notion of economic diversification in the long run: do communities use the short-term injection of economic activity associated with the mine to support other types of economic growth and development?

From these reviewed studies, one is left with as many questions as answers. While it is clear that the characteristics of the community where the mine is located create conditions for the economic consequences of mining, the extent is ambiguous. The literature is also clear that communities experiencing sudden booms will also experience short-term difficulties such as shortages in rental properties, increases in certain types of crime, and shortages in labor as workers shift to employment opportunities in the extractive industry. Further, local institutions, such as local governments and economic development organizations, can greatly influence the long-run effects of a mine. Because of the fundamental way in which prices of the extracted commodities influence mining operations, the community is exposed to movements in global prices. Generally, if global prices are strong, the mining operations can have a short-run positive impact on the community but if prices are weak the impacts can easily turn negative. More importantly, instability in global prices will translate into instability in the local economy. Finally, the degree of spatial dependence among communities where mining is pervasive can greatly affect the actions of local institutions and the scale of social difficulties.

3. A THEORETIC COMMUNITY ECONOMIC GROWTH FRAMEWORK

To model the relationship between non-oil and gas mining and community economic growth we employ an expanded version of the classic Carlino and Mills (1987) adjustment framework. [See Boarnet, Chalermpong, and Geho (2005) for a detailed review of studies using the Carlino and Mills framework.] We use the expanded version introduced by Deller et al. (2001) which has been subsequently used by Nzaku and Bukenya (2005), Deller and Lledo (2007), Hammond and Tosun (2011), Park et al. (2009), and Waltert, Schulz, and Schlapfer (2011).

We construct three central hypotheses in this research:

H1: Growth is conditional upon historical growth patterns.
H2: Growth is conditional upon initial conditions.
H3: Growth is conditional upon regional dependence on mining for employment.

The first two hypotheses are drawn directly from the Carlino and Mills framework and are consistent with other studies that have adopted this general theoretical approach. The last hypothesis is consistent with the objective of this research; specifically, what role does non-oil and gas mining play in community economic growth?

As outlined in Deller et al. (2001) the general form of the model is:

(1) $$\mathbf{p}^* = f(\mathbf{e}^*, \mathbf{i}^* \mid \boldsymbol{\Omega}^P)$$

(2) $$\mathbf{e}^* = g(\mathbf{p}^*, \mathbf{i}^* \mid \boldsymbol{\Omega}^E)$$

(3) $$\mathbf{i}^* = g(\mathbf{p}^*, \mathbf{e}^* \mid \boldsymbol{\Omega}^I)$$

Here, $\mathbf{p}^*$, $\mathbf{e}^*$ and $\mathbf{i}^*$ are equilibrium levels of population, employment and per capita income, and $\boldsymbol{\Omega}^P$, $\boldsymbol{\Omega}^E$ and $\boldsymbol{\Omega}^I$ are a set of variables describing initial conditions and other historical information. Contained in the latter set of information are measures of mining activity. This formulation expands the model of Carlino and Mills by explicitly introducing income into the structural framework. This latter addition to the general Carlino and Mills framework is intended to draw explicit attention to the question about job quality and wage levels.

Relying on the equilibrium conditions laid out above, a simple linear representation of those conditions can be expressed as:

(4) $$\mathbf{p}^* = \alpha_{op} + \beta_{1p}\,\mathbf{e}^* + \beta_{2p}\,\mathbf{i}^* + \Sigma\delta_{Ip}\,\boldsymbol{\Omega}^P$$

(5) $$\mathbf{e}^* = \alpha_{oE} + \beta_{1E}\,\mathbf{p}^* + \beta_{2E}\,\mathbf{i}^* + \Sigma\delta_{IE}\,\boldsymbol{\Omega}^E$$

(6) $$\mathbf{i}^* = \alpha_{oI} + \beta_{1I}\,\mathbf{p}^* + \beta_{2I}\,\mathbf{e}^* + \Sigma\delta_{II}\,\boldsymbol{\Omega}^I$$

Moreover, population, employment and income likely adjust to their equilibrium levels with substantial lags (i.e., initial conditions). The adjustment equations of the equilibrium levels are:

(7) $$\mathbf{p}_t = \mathbf{p}_{t-1} + \lambda_P\,(\mathbf{p}^* - \mathbf{p}_{t-1})$$

(8) $$\mathbf{e}_t = \mathbf{e}_{t-1} + \lambda_E\,(\mathbf{e}^* - \mathbf{e}_{t-1})$$

(9) $$\mathbf{i}_t = \mathbf{i}_{t-1} + \lambda_I\,(\mathbf{i}^* - \mathbf{i}_{t-1})$$

After slight rearrangement of terms this yields:

(10) $$\Delta\mathbf{p} = \mathbf{p}_t - \mathbf{p}_{t-1} = \lambda_P\,(\mathbf{p}^* - \mathbf{p}_{t-1})$$

(11) $$\Delta\mathbf{e} = \mathbf{e}_t - \mathbf{e}_{t-1} = \lambda_E\,(\mathbf{e}^* - \mathbf{e}_{t-1})$$

(12) $$\Delta\mathbf{i} = \mathbf{i}_t - \mathbf{i}_{t-1} = \lambda_I\,(\mathbf{i}^* - \mathbf{i}_{t-1})$$

Here, λ_P, λ_E and λ_I are speed of adjustment coefficients to the desired levels of population, employment and income, respectively, which are generally positive; $\Delta\mathbf{p}$, $\Delta\mathbf{e}$ and $\Delta\mathbf{i}$ are the region's changes in population, employment and per capita income respectively; $\mathbf{p}_{t-1}$, $\mathbf{e}_{t-1}$ and $\mathbf{i}_{t-1}$ are initial conditions of population, employment and per capita income. Substituting and rearranging terms allows us to express the linear representation of the model that is to be estimated as:

(13) $$\Delta\mathbf{p} = \alpha_{op} + \boldsymbol{\beta}_{\mathbf{1p}}\,\mathbf{p}_{t-1} + \boldsymbol{\beta}_{\mathbf{2p}}\,\mathbf{e}_{t-1} + \boldsymbol{\beta}_{\mathbf{3p}}\,\mathbf{i}_{t-1} + \gamma_{1p}\Delta\mathbf{e} + \gamma_{2p}\Delta\mathbf{i} + \Sigma\delta_{Ip}\boldsymbol{\Omega}^P$$

(14) $$\Delta\mathbf{e} = \alpha_{oE} + \boldsymbol{\beta}_{\mathbf{1E}}\,\mathbf{p}_{t-1} + \boldsymbol{\beta}_{\mathbf{2E}}\,\mathbf{e}_{t-1} + \boldsymbol{\beta}_{\mathbf{3E}}\,\mathbf{i}_{t-1} + \gamma_{1E}\Delta\mathbf{p} + \gamma_{2E}\Delta\mathbf{i} + \Sigma\delta_{IE}\boldsymbol{\Omega}^E$$

(15) $$\Delta\mathbf{i} = \alpha_{oI} + \boldsymbol{\beta}_{\mathbf{1I}}\,\mathbf{p}_{t-1} + \boldsymbol{\beta}_{\mathbf{2I}}\,\mathbf{e}_{t-1} + \boldsymbol{\beta}_{\mathbf{3I}}\,\mathbf{i}_{t-1} + \gamma_{1I}\Delta\mathbf{e} + \gamma_{2I}\Delta\mathbf{p} + \Sigma\delta_{II}\boldsymbol{\Omega}^I$$

Note that the speed of adjustment coefficient (λ) becomes embedded in the linear coefficient parameters α, β, γ, and δ. This framework is particularly useful for this analysis because it allows us to capture structural relationships while simultaneously isolating the influence of mining attributes on regional economic growth. In essence, we are modeling short-term adjustments (i.e., $\Delta\mathbf{p}$, $\Delta\mathbf{e}$ and $\Delta\mathbf{i}$) to long-term equilibrium (i.e., $\mathbf{p}^*$, $\mathbf{e}^*$ and $\mathbf{i}^*$). To simplify the model we estimate a reduced form of Equations (13)-(15), in other words $\mathbf{\Omega}^P$, $\mathbf{\Omega}^E$, $\mathbf{\Omega}^I$ include the same independent variables. Empirically, the growth metrics ($\Delta\mathbf{p}$, $\Delta\mathbf{e}$ and $\Delta\mathbf{i}$) are measured as a simple percent change.

4. EMPIRICAL MODEL

The empirical analysis has two challenges: (1) how to measure appropriately the level of dependency on mining as part of the community's economic base, and (2) how to determine the set of control variables contained in $\mathbf{\Omega}$. For measures of mining dependency, we are limited to the use of employment data for non-oil and gas extractive mining represented by NAICS 212 which includes sand and gravel mining, metallic mining and coal mining. We use the ratio of mining employment to population ratio (mean is 0.0302, standard deviation is 0.3034) along with mining employment as a share of total employment (mean is 0.0109, standard deviation is 0.0417). Both measures are scale-based relative to the overall size of the community (i.e., county) economy. Because population and total employment tends to be correlated, it is not surprising that our two measures of dependency on mining for employment are also correlated (correlation coefficient is 0.7110). By using both measures of mining activity we can address the robustness of our results in a simplistic manner.

The selection of the other control variables comprising $\mathbf{\Omega}$ has proven to be one of the most controversial issues in the empirical growth literature (Brock and Durlauf, 2001; Durlauf and Quah, 1999; Sala-i-Martin, 1997). Since the seminal article by Levine and Renelt (1992), the robustness of empirical growth models have been widely challenged based on the selection of the control variables.[2] Specifically, Levine and Renelt observed that key results, such as convergence rates in neo-classical based models, are sensitive to selection of control variables. Today, it is common for researchers to explore alternative specifications to explore the sensitivity, or robustness, of the key variables of interest.

For this study we rely on the previous work of rural researchers, particularly Deller and Lledo (2007), who use a Bayesian Model Averaging method to identify a set of control variables that are the most consistent with the underlying data generating process. The variables used in this analysis are population in 2000, employment in 2000, per capita income in 2000, percent of the population over age 65, ethnic diversity index, percent of the population over age 25 with a bachelor degree in 2000, percent of the population foreign born in 2000, percent of the population speaks a language other than English at home in 2000, percent of the population living in same residence in 2000 as in 1995, and poverty rate in 2000.

The first three, population, employment and per capita income at the beginning of the period are taken directly from Equations (13-15) and are not part of the control variables contained in $\mathbf{\Omega}$. Percent of the population over age 65 is aimed at reflecting labor supply and to

[2] Although Levine and Renelt (1992) are particularly critical of Barro-type empirical convergence models that flow from neo-classical growth theory, the overall observations can be readily applied to any type of empirical growth models.

capture the aging of rural areas. The diversity index is calculated as $\left[1-\sum_i (race_i^2)\right]*100$ where *race* is the percent of the population across different ethnic groups. Racially heterogeneous communities tend to have more variation among economic preferences and social ties, which makes any collective action efforts to constrain mining activities more challenging to local residents (Rupasingha et al., 2004). Percent of the population with a bachelor's degree is intended to control for human capital. Percent of the population that is foreign born along with percent of persons speaking a language other than English at home is intended to capture the growing Hispanic population and other foreign immigrants. Percent of the population living in the same residence in 2000 as in 1995 is an attempt to capture community stability or turn-over. Finally, the poverty rate is a proxy for wealth within the community and an additional measure of human capital.

One of the limitations of a minimal set of control variables is the potential for omitted variable bias. We know, for example, that mining activity is sensitive to world commodity prices, for which we should control in our analysis. Unfortunately, because we are using non-oil and gas mining (NAICS 212) activities as our variable of interest there is no corresponding aggregate price index. In addition, because we are using a cross section in 2000 and commodity prices are determined in global markets, there would be no variation across counties. Keeping the set of control variables simple may introduce omitted variable bias, which may overstate the influence of mining activity on our three metrics of economic growth.

A set of tests for spatial dependency in the growth models suggests that simple regression analysis will prove to be problematic (Table 1). This makes intuitive sense given the geographic concentrations of mineral resources, such as frack sand in western Wisconsin and southeastern Minnesota. As a result we use two spatial estimators including the spatial lag ($\mathbf{g} = \rho\mathbf{W}\boldsymbol{g} + \boldsymbol{X\beta} + \boldsymbol{\varepsilon}$, $\boldsymbol{\varepsilon} \sim \mathrm{N}(0,\boldsymbol{\sigma}^2)$, and W is a traditional row-standardized spatial weights matrix) as well as a spatial error model ($\mathbf{g} = \boldsymbol{X\beta} + \boldsymbol{\varepsilon}$, $\boldsymbol{\varepsilon} = \lambda\mathbf{W}\boldsymbol{\varepsilon} + \boldsymbol{\mu}$, $\boldsymbol{\mu} \sim \mathrm{N}(0,\boldsymbol{\sigma}^2)$). This gives us a total of twelve models to report: three measures of economic growth, two measures of mining activity, and two estimators.

Table 1: Spatial Correlation in Residuals: Nonmetropolitan U.S. Counties

	Population Growth		Employment Growth		Per Capital Income Growth	
	Test stat.	p-value	Test-stat	p-value	Test stat.	p-value
			Mining Population Ratio			
Moran's I	0.3250	0.0001	0.1962	0.0001	0.1962	0.0001
Lagrange Multiplier	623.3927	0.0001	227.1433	0.0001	227.1433	0.0001
Likelihood Ratio	468.4936	0.0001	179.6325	0.0001	179.6325	0.0001
			Mining Employment Share			
Moran's I	0.3258	0.0001	0.1958	0.0001	0.1958	0.0001
Lagrange Multiplier	626.6146	0.0001	226.3612	0.0001	226.3612	0.0001
Likelihood Ratio	469.7381	0.0001	180.5232	0.0001	180.5232	0.0001

From these twelve models, we can infer the robustness of our results on the central question: does higher dependency on non-oil and gas mining activity lead to higher levels of economic growth in nonmetropolitan U.S. communities?

5. EMPIRICAL RESULTS

Consider first the population growth results (Table 2), then the employment results (Table 3) and then the per capita income results (Table 4) in turn. The models explain between 43 to 57 percent of the variation in population growth based on the estimated R^2, which is generally consistent with other studies exploring rural population growth. The spatial lag model parameters, ρ, as well as the spatial error parameters, λ, are all statistically significant as expected given the spatial dependency results outlined in Table 1. Larger counties, as measured by population, tend to experience higher rates of population growth but rural counties with larger employment tend to experience slower rates of population growth. The results on the role of lagged per capita income on population growth, however, are not stable across the spatial lag and error estimators. The coefficients are consistently negative, suggesting that higher income rural counties experienced slower population growth over the study period, however, they are only weakly significant in the spatial-lag estimated models.

Table 2: Mining Dependency and Rural Population Growth, 2000 to 2007

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	0.2766 (0.0192) [0.0000]	0.2779 (0.0192) [0.0000]	0.3366 (0.01468) [0.0000]	0.3380 (0.0292) [0.0000]
Population 2000	0.0127 (0.0021) [0.0000]	0.0130 (0.0021) [0.0000]	0.0156 (0.0022) [0.0000]	0.0156 (0.0025) [0.0000]
Employment 2000	-0.0165 (0.0041) [0.0001]	-0.0172 (0.0042) [0.0000]	-0.0222 (0.0042) [0.0000]	-0.0223 (0.0044) [0.0000]
Per Capita Income 2000	-0.0083 (0.0043) [0.0536]	-0.0083 (0.0043) [0.0527]	-0.0042 (0.0038) [0.2655]	-0.0042 (0.0051) [0.4076]
Percent of the Population Over Age 65	-0.7749 (0.0579) [0.0000]	-0.7703 (0.0588) [0.0000]	-0.9308 (0.0722) [0.0000]	-0.9556 (0.0730) [0.0000]
Ethnic Diversity Index	-0.0020 (0.0087) [0.8156]	-0.0041 (0.0088) [0.6370]	-0.0092 (0.0128) [0.4733]	-0.0102 (0.0132) [0.4367]
Percent of the Population Over Age 25 with a Bachelor Degree 2000	0.0353 (0.0283) [0.2128]	0.0351 (0.0283) [0.2149]	-0.0073 (0.0327) [0.8237]	-0.0097 (0.0353) [0.7826]

Table 2 (cont.): Mining Dependency and Rural Population Growth, 2000 to 2007

Variable	Model 1	Model 2	Model 3	Model 4
Percent of the Population Foreign Born 2000	0.0041 (0.0500) [0.9354]	0.0033 (0.0500) [0.9466]	0.0702 (0.0588) [0.2326]	0.0739 (0.0615) [0.2295]
Percent of the Population Speaks a Language Other than English at Home 2000	-0.0055 (0.0192) [0.7761]	-0.0078 (0.0192) [0..6836]	-0.0152 (0.0268) [0.5712]	-0.0181 (0.0275) [0.5094]
Percent of the Population Living in Same Residence in 2000 as in 1995	-0.3081 (0.0229) [0.0000]	-0.3047 (0.0229) [0.0000]	-0.3783 (0.0270) [0.0000]	-0.3738 (0.0299) [0.0000]
Poverty Rate 2000	-0.1966 (0.0354) [0.0000]	-0.1955 (0.0354) [0.0000]	-0.2534 (0.0362) [0.0000]	-0.2568 (0.0527) [0.0000]
Mining Employment to Population Ratio	-0.0103 (0.0039) [0.0087]	----	-0.0086 (0.0039) [0.0286]	----
Mining Share of Employment	----	-0.0935 (0.0290) [0.0013]	----	-0.0986 (0.0318) [0.0019]
Spatial Lag ρ	0.5180 (0.0120) [0.0000]	0.5150 (0.0121) [0.0000]	----	----
Spatial Error λ	----	----	0.5710 (0.0328) [0.0000]	0.5720 (0.0333) [0.0000]
R^2	0.4297	0.4298	0.5742	0.5754
Sum of Squared Errors	7.44	7.44	7.69	7.68

Note: The figures are stacked by coefficient value, standard errors, *p*-values. Standard errors are reported in parentheses while p-values are reported in brackets.

The results for the control variables are consistent across all four specifications of the population growth model, lending confidence to the robustness of the results. As expected, an older population has a dampening effect on population growth as does residential stability and the poverty rate. Ethnic diversity, defined as the percent of the population foreign born and percent of the population that speaks non-English languages at home, does not appear to influence rural population growth. Somewhat surprisingly, percent of the population over age 25 with a bachelor's degree, our measure of human capital, does not appear to influence population growth. The results of our two measures of non-oil and gas mining dependency, ratio of mining employment to population and mining employment as a share of total employment, are consistently negative and statistically significant for both the spatial lag and error estimators. This suggests that rural counties that are more dependent on mining for economic activity experienced slower population growth rates.

The explanatory power of the employment growth model (Table 3) is weaker than the population models with between 22 and 29 percent of the variation in rural employment growth explained. This is consistent with other studies examining rural employment growth patterns. As expected, the spatial lag model parameters, ρ, and the spatial error parameters, λ, are all statistically significant. We find that higher initial levels of population have a positive impact on employment growth, but both higher levels of employment and per capita income have a dampening impact on employment growth. If we return to the original question offered first by Steinnes and Fisher (1974) and later by Carlino and Mills (1987): "Do people follow jobs or do jobs follow people?" the results in Tables 2 and 3 suggest that population is the driving factor, or jobs follow people. Broad conclusions, however, may not be directly applicable to certain racial subdivisions. As is evident from Table 3, the percent of the population that speaks a language other than English at home has a strong positive impact on employment growth. While the analysis presented here is not sufficient to draw any direct inferences, this latter result may be a reflection of the large migration of Hispanics to areas with more employment opportunities and is consistent with the finding of Lichter and Johnson (2009).

Table 3: Mining Dependency and Rural Employment Growth, 2000 to 2007

Variable	Model 5	Model 6	Model 7	Model 8
Intercept	20.8855 (3.5465) [0.0000]	20.9339 (3.5262) [0.0000]	26.4296 (4.8441) [0.0000]	26.4888 (4.8833) [0.0000]
Population 2000	2.8158 (0.4165) [0.0000]	2.7926 (0.4107) [0.0000]	2.9019 (0.4560) [0.0000]	2.8815 (0.4567) [0.0000]
Employment 2000	-5.2965 (0.8069) [0.0000]	-5.2603 (0.7957) [0.0000]	-5.4208 (0.8529) [0.0000]	-5.3928 (0.8535) [0.0000]
Per Capita Income 2000	-2.3428 (0.8000) [0.0034]	-2.3398 (0.7998) [0.0034]	-2.4260 (0.8914) [0.0065]	-2.4387 (0.8935) [0.0063]
Percent of the Population Over Age 65	-76.2287 (11.2741) [0.0000]	-76.7389 (11.3545) [0.0000]	-86.5346 (13.2000) [0.0000]	-87.8795 (13.3607) [0.0000]
Ethnic Diversity Index	1.2163 (1.6761) [0.4680]	1.1811 (1.6805) [0.4822]	1.1721 (2.2287) [0.5989]	1.0966 (2.2345) [0.6236]

Table 3 (cont'd): Mining Dependency and Rural Employment Growth, 2000 to 2007

Variable	Model 5	Model 6	Model 7	Model 8
Percent of the Population Over Age 25 with a Bachelor Degree 2000	47.7149 (5.4712) [0.0000]	47.4369 (5.4087) [0.0000]	48.5795 (6.6242) [0.0000]	48.4973 (6.6492) [0.0000]
Percent of the Population Foreign Born 2000	-2.3336 (9.5496) [0.8075]	-2.1929 (9.5686) [0.8187]	-4.9344 (11.2974) [0.6623]	-4.5621 (11.3031) [0.6865]
Percent of the Population Speaks a Language Other than English at Home 2000	10.8024 (3.6935) [0.0034]	10.6936 (3.6787) [0.0037]	15.7293 (4.6936) [0.0008]	15.5420 (4.6978) [0.0009]
Percent of the Population Living in Same Residence in 2000 as in 1995	-19.1936 (4.4091) [0.0000]	-19.0769 (4.3959) [0.0000]	-23.1768 (5.4053) [0.0000]	-22.8568 (5.4161) [0.0000]
Poverty Rate 2000	-26.6359 (6.5859) [0.0001]	-26.7920 (6.5764) [0.0000]	-34.9205 (8.6851) [0.0001]	-35.1549 (8.7210) [0.0001]
Mining Employment to Population Ratio	0.8323 (0.7511) [0.2678]	----	0.7491 (0.7666) [0.3285]	----
Mining Share of Employment	----	0.6033 (5.5613) [0.9136]	----	-1.6874 (6.1129) [0.7825]
Spatial Lag ρ	0.3980 (0.0265) [0.0000]	0.4030 (0.0105) [0.0000]	----	----
Spatial Error λ	----	----	0.3940 (0.0363) [0.0000]	0.3940 (0.0369) [0.0000]
R^2	0.2202	0.2191	0.2928	0.2925
Sum of Squared Errors	229,910.00	230.240.00	236,670.00	237,100.00

Note: The figures are stacked by coefficient value, standard errors, p-values. Standard errors are reported in parentheses while p-values are reported in brackets.

Among the other control variables, an older population has a dampening impact on employment growth as does residential stability and the poverty rate. Ethnic diversity does not appear to impact employment growth nor does the percent of the population that is foreign born. As expected, the higher the level of human capital measured by college education levels is associated with higher employment growth rates. Our measures of mining activity have no influence on employment growth; each of the four estimated parameters is statistically insignificant. All of these results are consistent across all four specifications, lending evidence of the robustness of the results. This result might be partially explained by the movement of mining away from a labor to a more capital intensive industry. In addition, as noted by Freudenberg and Gramling (1994), many mining employees are geographically highly mobile and are more likely to send earnings to family members at their more permanent residences. In addition, the potential instability in mining activities may dampen the creation of employment generating consumer focused businesses such as restaurants and retail.

Now consider the per capita income growth models (Table 4). The models explain between 24 percent of the variation in growth in per capita income for the spatial lag models to almost 41 percent for the spatial error models. Consistent with the population and employment growth models, the spatial parameters (ρ, λ) are statistically significant. Initial levels of population and employment have no statistically significant influence in explaining growth in per capita income. Higher initial levels of per capita income, however, are associated with slower growth rates in per capita income. This result is consistent with the central hypothesis of convergence that flows from neoclassical growth theory, a result that has been regularly observed in rural growth models.

Table 4: Mining Dependency and Rural Per Capita Income Growth, 2000 to 2007

Variable	Model 9	Model 10	Model 11	Model 12
Intercept	0.0615 (0.0378) [0.1034]	0.0597 (0.0377) [0.1134]	0.2578 (0.0503) [0.0000]	0.2534 (0.0502) [0.0000]
Population in 2000	-0.0020 (0.0044) [0.6581]	-0.0024 (0.0044) [0.5886]	-0.0058 (0.0049) [0.2345]	-0.0057 (0.0049) [0.2439]
Employment in 2000	-0.0077 (0.0086) [0.3721]	-0.0065 (0.0086) [0.4500]	-0.0001 (0.0090) [0.9912]	-0.0001 (0.0091) [0.9870]
Per Capita Income in 2000	-0.0678 (0.0086) [0.0000]	-0.0677 (0.0086) [0.0000]	-0.0773 (0.0093) [0.0000]	-0.0772 (0.0093) [0.0000]
Percent of the Population Over Age 65	0.3625 (0.1223) [0.0030]	0.4114 (0.1242) [0.0009]	0.4185 (0.1589) [0.0084]	0.4704 (0.1607) [0.0034]
Ethnic Diversity Index	0.0237 (0.0180) [0.1897]	0.0279 (0.0181) [0.1235]	0.0136 (0.0272) [0.6173]	0.0161 (0.0272) [0.5540]

Table 4 (cont.): Mining Dependency and Rural Per Capita Income Growth, 2000 to 2007

Variable	Model 9	Model 10	Model 11	Model 12
Percent of the Population Over Age 25 with a Bachelor Degree in 2000	0.5795 (0.0600) [0.0000]	0.5799 (0.0600) [0.0000]	0.6571 (0.0753) [0.0000]	0.6657 (0.0752) [0.0000]
Percent of the Population Foreign-Born in 2000	0.0011 (0.1010) [0.9917]	0.0022 (0.1028) [0.9831]	-0.1598 (0.1263) [0.2060]	-0.1663 (0.1262) [0.1877]
Percent of the Population Speaks a Language Other than English at Home, 2000	0.1335 (0.0401) [0.0009]	0.1380 (0.0401) [0.0006]	0.2087 (0.0576) [0.0003]	0.2169 (0.0574) [0.0002]
Percent of the Population Living in Same Residence in 2000 as in 1995	0.2491 (0.0473) [0.0000]	0.2412 (0.0474) [0.0000]	0.3010 (0.0598) [0.0000]	0.2928 (0.0598) [0.0000]
Poverty Rate in 1999	-0.1394 (0.0708) [0.0489]	-0.1415 (0.0707) [0.0452]	-0.2039 (0.0967) [0.0350]	-0.1946 (0.0965) [0.0436]
Mining Employment to Population Ratio	0.0158 (0.0081) [0.0502]	----	0.0112 (0.0083) [0.1771]	----
Mining Share of Employment	----	0.1785 (0.0600) [0.0029]	----	0.1599 (0.0671) [0.0172]
Spatial Lag ρ	0.5780 (0.0220) [0.0000]	0.5780 (0.0221) [0.0000]	----	----
Spatial Error λ	----	----	0.5580 (0.0279) [0.0000]	0.5510 (0.0280) [0.0000]
R^2	0.2430	0.2490	0.4067	0.4062
Sum of Squared Errors	31.37	31.12	34.46	34.21

Note: The figures are stacked by coefficient value, standard errors, *p*-values. Standard errors are reported in parentheses while *p*-values are reported in brackets.

Of all the control variables, only the poverty rate has a statistically significant negative impact on per capita income growth rates. Conversely, an older population, measured by percent of the population over age 65, along with higher levels of human capital proxied by college education levels, percent of the population that speaks a language other than English at home, and residential stability are all statistically significant and associated with higher growth rates in per capita income. Ethnic diversity and percent of the population foreign born have no influence on income growth. The results on our mining metrics suggest that higher levels of mining activity tend to be associated with higher growth rates in per capita income. For mining employment as a share of total employment the estimated parameter is positive and statistically significant for both the spatial lag and error models. But for the mining employment to population ratio, the positive parameter is significant for the spatial lag estimated model but is statistically insignificant for the spatial error estimated model. This last result proposes some ambiguity concerning the robustness of the impact of mining on per capita income growth.

We can draw three basic conclusions about the influence of non-oil and gas mining on rural U.S. communities from our results. Higher levels of mining employment are associated with lower population growth and higher levels of income growth. Higher mining employment has no influence on employment growth. Several observations can be drawn from our results and the available literature. Mining is moving from a labor to capital intensive industry that has shifting occupational requirements. This suggests that mining may no longer provide a strong source of employment within a locality but the jobs are better paying than alternative jobs in these communities. Mining operations bring transitory workers into the community who have weak ties to the local economy and may be transferring earnings to locations outside the mining community. In addition, the inherent instability of mining as an industry may limit further business development. Any spillover or employment multiplier effect may be modest. Further, the results suggest that individuals may avoid locating in mining-dependent areas, thus weakening the potential for strategies to diversify the local economy.

Perhaps more importantly, the mixed results across population, employment and income growth models suggest that broad generalizations about economic growth and non-oil and gas mining cannot be made. Higher levels of mining employment have different implications, depending on the metric of economic growth used. Whether a rural community should or should not pursue mining as an economic growth policy depends on the community's objective. If the community seeks to expand the population base, the promotion of mining may be detrimental to the community's goals. If the community plans to expand employment, it is not clear from this analysis that mining is a way to satisfy that goal. If the community's goal is to raise income levels, then mining might be an appropriate strategy to consider.

6. CONCLUSIONS

With the aggressive introduction of hydraulic fracturing, or "fracking", to remove natural gas and oil from rock formations 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), mining as a community economic growth strategy is gaining significant attention. While the Marcellus and Bakken fields are receiving the majority of media attention, there has been strong growth in non-oil and gas mining activity. In the case of western Wisconsin and southeastern Minnesota the demand for frack sand has created a gold rush mentality in many rural communities. In addition, the increasing world demand for many minerals has seen growth in mining activities in many parts of the rural U.S.

The necessary issue, then, is whether the promotion of mining provides an appropriate economic growth strategy for rural communities. The literature is mixed. Results vary by the nature of mining explored, the time period examined, and the metric of economic growth and development used. The results presented here suggest that a higher level of dependency on non-oil and gas based mining, such as frack sand mining or other mineral mining, does not lead to higher levels of population and employment growth, but does have a positive impact on income growth. Indeed, we find that mining may have a detrimental impact on population growth.

Mining is less labor-intensive than in the past, requiring fewer, but potentially higher paying jobs. The mining workforce also tends to be more transient, moving from one mining operation to another. This more transient workforce has weaker ties to the local community both socially and economically. The best example of this phenomenon in the extreme is the "man camps" that are being created in the more remote frack gas/oil production operations.

The flickering of mineral mining in response to swings in global commodity prices can also shed light on the empirical findings reported here. While we do not explicitly model stability, the case-study-based literature has noted that mining employees often plan for these periods of unemployment through increased savings during periods of work. With the recent drop in natural gas prices there has been a noticeable slow-down in new natural gas fracking mines. This has already had direct impacts on frack sand mining in Wisconsin and Minnesota with some sand mines moving from a seven day per week operational schedule to a four day per week and the opening of new mines postponed. This uncertainty over employment stability results in altered spending patterns in the local community. It has been argued that this uncertainty places a limit on the expansion of retail and personal service businesses one would expect with employment growth. We return to the observation of Weinstein and Partridge (2011) who note that many economic impact studies overstate the potential impact. The uncertainty resulting from the inherent instability of mining helps us understand why the multiplier spillovers are often smaller than one might expect.

The analysis presented here has limitations. We use an aggregate measure of mining (non-oil and gas mining—NAICS 212) and results may differ if a more refined definition of mining was explored. The time-period examined does not reflect an actual fracking boom and covers only a seven year period; future work may consider using longer and overlapping time-periods. While we control for spatial dependency, the global parameter estimation method used in this study may be masking important spatial heterogeneity in the underlying data generating processes. The use of a geographically weighted regression type estimator may reveal that the processes linking mining and community economic growth may vary over space. Finally, additional work is required in determining the set of control variables to be included in the growth models. It is clear the global commodity prices play a central role in the relationship between mining and community economic growth and additional thought on how to introduce this into our regional growth models is required.

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