The Economic Impact of Shale Gas Development: A Natural Experiment along the New York / Pennsylvania Border

Brendan M. Cosgrove, Daniel R. LaFave, Sahan T. M. Dissanayake, and Michael R. Donihue

We investigate local economic impacts of shale gas development using the natural experiment of the discontinuity in regulation caused by New York's 2008 moratorium on fracking. Using county- and zip-code-level data for 2001–2013 to examine differences in New York and Pennsylvania counties before and after the moratorium, we find that shale gas development has a positive local impact on employment and wages in the natural resource, mining, and construction sectors and an offsetting reduction in employment in the manufacturing sector. Overall, we find no statistically significant local effects on total employment or on wages.

Key Words: difference-in-differences, economic impact, fracking, Marcellus shale, natural experiment, shale gas development

Over the past decade, the technological advancements of hydraulic fracturing and horizontal drilling have led to the economic feasibility and rapid growth of natural gas production using shale and other unconventional sources. Hydraulic fracturing ("fracking") is the process of injecting pressurized fluids into shale gas deposits to create a network of cracks in the formations at 5,000 to 10,000 feet below the earth's surface. These cracks release natural gas trapped in the underground shale formations, allowing it to flow into wells at the surface. More than 99 percent of the fracking fluid is water; the remainder is a combination of sand and chemicals (Higginbotham et al. 2010).

Brendan M. Cosgrove was an undergraduate student in the Department of Economics at Colby College. Daniel R. LaFave and Sahan T. M. Dissanayake are assistant professors in the Department of Economics at Colby College. Michael R. Donihue is the Herbert E. Wadsworth professor in the Department of Economics at Colby College. Corresponding author: *Sahan T. M. Dissanayake ▪ 5230 Mayflower Hill ▪ Waterville, ME 04901-8852 ▪ Phone 217.419.0452 ▪ Email sdissan2@gmail.com*.

We are grateful to two anonymous referees and to participants at the 2014 Northeastern Agricultural and Resource Economics Association workshop on unconventional oil and gas energy, the 2014 Maine Economics Conference, and the 2014 Colby College Liberal Arts Symposium for comments and discussion. We thank Manny Gimond for his help with the ArcGIS data and Colby College for financial support granted with the Special Project Award and the Dean's Fund for Academic Innovation Award.

This paper is included as part of the special issue of *Agricultural and Resource Economics* related to the workshop "Unconventional Gas and Oil Development: Economic and Environmental Impacts" organized by the Northeastern Agricultural and Resource Economics Association and held in Morgantown, West Virginia, on June 3 and 4, 2014. The authors and editors acknowledge and thank the National Agricultural and Rural Development Policy Center and the U.S. Department of Agriculture National Institute of Food and Agriculture for funding under competitive grant 2012-70002-1938. Additional support was provide by the Davis College of Agriculture, Natural Resources, and Design's Office of Sponsored Programs and the Regional Research Institute, both of West Virginia University. The views expressed are the authors' and do not necessarily represent the policies or views of any sponsoring agencies.

The rapid evolution of shale gas development is expected to allow for an increase in the U.S. supply of natural gas to meet domestic demand for electricity and to position the United States to become a net exporter of the product by 2019 (Energy Information Administration (EIA) 2013). Currently, more than half of the natural gas produced in the United States comes from unconventional sources such as deep gas deposits, tight gas deposits, shales, coal-bed methane deposits, and geopressurized zones (Jacquet 2012). Between 2000 and 2009, approximately 190,000 conventional and unconventional natural gas wells were drilled (Jacquet 2012), and shale production was expected to grow from 7.85 trillion cubic feet in 2011 to 16.70 trillion cubic feet in 2014 (EIA 2013). With an estimated annual growth rate of 2.6 percent, shale gas development is the largest of potential sources of growth in the domestic supply of natural gas (EIA 2013).

The largest deposits in the United States are found in the Marcellus shale, which covers 95,000 square miles spanning Ohio, West Virginia, New York, Pennsylvania, and parts of western Maryland and Virginia. The shale is estimated to contain 141 trillion cubic feet of recoverable natural gas representing nearly 30 percent of all domestic reserves (EIA 2012). It dates to more than 350 million years ago and consists of relatively coarsely grained sandstone, siltstone, and shale (Higginbotham et al. 2010). Its low permeability and relatively deep depths restricted the ability to extract the gas by conventional methods, but the introduction of fracking and horizontal drilling techniques transformed the energy potential of the Appalachian Basin. These innovations led to rapid expansion of natural gas production in Pennsylvania—from 332 unconventional wells drilled in 2008 to 1,352 in 2012 (Pennsylvania Department of Environmental Protection 2015)—and shale gas withdrawals, as shown in Figure 1, increased from a few billion cubic feet per month in 2009 to more than 250 billion cubic feet per month in 2013 (EIA 2014).

Simultaneously, shale gas development has sparked debate over potential risks to human health and the environment. Opponents assert that fracking

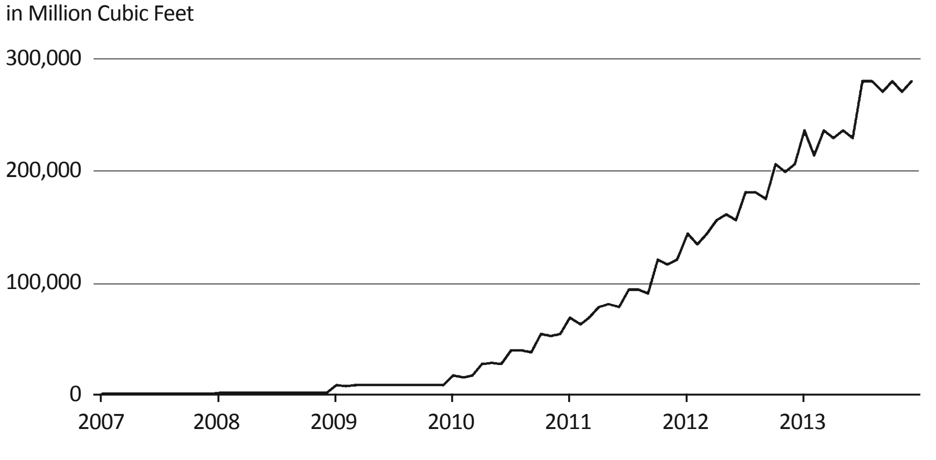

Figure 1. Natural Gas Withdrawals from Shale Gas in Pennsylvania

Source: U.S. Energy Information Administration (www.eia.gov/dnav/ng/hist/ngm_epg0_fgs_spa_mmcfm.htm).

increases the risk already posed by gas extraction of contaminating ground water, depletes local aquifers, releases methane into the atmosphere, and damages local infrastructures and ecosystems. Supporters of shale gas development stress its potential economic benefits, its role in a diversified U.S. energy portfolio, and the role of properly designed regulations to mitigate potential concerns about health and the environment (e.g., Brasier et al. 2011, Howarth, Ingraffea, and Engelder 2011).

While shale gas development may provide measurable benefits such as new jobs, tax revenue, and reductions in greenhouse gas emissions relative to other fossil fuels, the industry currently represents considerably less than 1 percent of the U.S. economy, and its impact on local economies is uncertain. A number of recent studies have predicted that shale gas will create millions of jobs and billions in tax revenue and added value nationwide in the next twenty years. For example, according to IHS (2012), an industry consulting firm, by 2035 the United States will invest more than $3 trillion in capital expenditures for unconventional natural gas activity, employment in the industry is expected to grow 3.76 percent annually to support more than 2.1 million jobs, and tax revenues are expected to grow 3.06 percent annually and contribute approximately $60 billion to federal, state, and local governments. The same report also projects that the shale gas industry will add $287.1 billion to the country's gross domestic product (GDP) in 2035. At the same time, however, other studies have found much smaller and less certain estimates of the industry's economic impacts (Mauro et al. 2013).

We estimate regional economic impacts of shale gas development using a discontinuity in fracking regulation at the New York / Pennsylvania border as a natural experiment. As the modern-day gas rush was under way in Pennsylvania in the mid-2000s, New York in 2008 placed a statewide moratorium on fracking to allow for a comprehensive evaluation of its economic and environmental impacts. We use that moratorium, which remains in place today, in a difference-in-differences framework to evaluate the economic impacts of fracking on the local economy. We use county- and zip-code-level data for 2001–2013 applied to multiple geographic subsets to test the robustness of the results. While the initial analysis uses data from all counties on the New York / Pennsylvania border, the bulk of the analysis focuses only on the areas in Pennsylvania in which shale development has been intensive. We then expand the analysis to account for possible spillover effects from New York counties by using two distance bands from the border to select counties/zip codes.

We find that shale gas development between 2001 and 2013 has led to a statistically significant increase in employment and wages in the natural resource and mining industry and construction industry in Pennsylvania counties in which drilling occurred. However, we also find an offsetting reduction in employment in the manufacturing sector and no statistically significant effects from fracking on total employment and wages at a local level. The results present a nuanced view of the often isolated impacts of shale extraction on local economies associated with the Marcellus.

Studies of the Economic Impacts from Shale Gas Development

Industry-funded studies conducted using input-output (IO) models have suggested that shale gas development has produced major economic benefits at a state level. The IO model, which is based on historical relationships within the local economy or similar economies, uses regional multipliers to follow the flow of capital from an initial stimulus, thus estimating the cascading effects of spending in one industry on the greater economy (PricewaterhouseCoopers 2013). The resulting estimates allow one to decompose the total economic impact of shale development into direct impacts of expenditures by the industry, indirect impacts from the initial stimulus as capital flowed between sectors, and induced benefits from spending by households that directly or indirectly received benefits from gas development as their incomes increased. For example, total spending on shale development in Pennsylvania in 2009 was $4.5 billion (Considine, Watson, and Blumsack 2010). According to IO estimates, the benefits of that spending include more than 44,000 new jobs, $389 million in state and local tax revenue, and $3.9 billion in GDP (Considine, Watson, and Blumsack 2010). Extrapolating forward to 2015, the number of natural gas wells drilled was predicted to nearly quadruple—from 710 in 2009 to 2,903—and create more than 160,000 new jobs, $1.4 billion in state and local tax revenue, and $14.5 billion in value added (Considine, Watson, and Blumsack 2010). Similar but smaller impacts are identified by Kelsey et al. (2011) for Pennsylvania.

As in Pennsylvania, West Virginia experienced job growth, increased tax revenue, and higher GDP levels according to an IO-based study. Higginbotham et al. (2010) found that Marcellus shale development in West Virginia in 2009 created an estimated 24,000 jobs, $110 million in state and local tax revenue, and $3.1 billion in total value added. In addition, gas development in West Virginia generated higher levels of per capita income for residents by paying more than $550 million in wages (Higginbotham et al. 2010). Similar benefits were found in Arkansas (Center for Business and Economic Research 2008); development in the Fayetteville shale created an estimated 9,500 jobs in 2007.

With IO models, estimated impacts are sensitive to assumptions made in the methodology (true for other empirical methods as well). Kinnaman (2011) and Mauro et al. (2013) noted that industry-sponsored studies tended to produce higher estimates of the economic impacts of shale gas development than academic studies that used the same IO method. Critiques of the IO approach have focused on the validity of (i) using multipliers that are based on existing inter-industry links in one region as a proxy for future activity in a new region, (ii) assumed homogeneity of individuals that is conditional on income, and (iii) the static nature of the estimates. Each of these issues can lead to overestimates. Regional economic multipliers that link one industry in a region to all other industries are at the heart of IO models (Barth 2013, Mauro et al. 2013). However, for areas that lack a developed natural gas industry, there is no way to determine region-specific economic multipliers from historical relationships since they do not exist. The IO models in these studies have used regional economic multipliers from regions in which natural gas has been developed, but those multipliers may not accurately represent the relationships between the industries in the region studied (Stimson, Stough, and Roberts 2006). Moreover, such studies hold regional economic multipliers and prices constant over time and may fail to capture the particularly dynamic behaviors that are typical of early development of a natural gas field (Black, McKinnish, and Sanders 2005).

Wooldridge (2012) noted that standard IO models treat all individuals as having identical spending patterns. When using IMPLAN, one often relaxes this assumption by allowing spending to vary based on household income, but the issue of assumed homogeneity of transient and stable workers conditional on income remains. For example, regions with an established natural gas industry may be able to hire primarily local workers, but newly developing regions that have few skilled workers will have to rely on nonlocal workers who typically take some or all of their earnings elsewhere. In addition, the majority of IO studies have assumed that 95 percent of direct industry spending stays in the region (Kinnaman 2011), and the assumption of identical spending patterns across worker-types may overestimate the economic impacts if a significant portion of the labor force is comprised of temporary workers since they may spend a relatively large share of their incomes on goods and services purchased outside the local economy.

Finally, the IO model ignores the possibility that direct spending by the industry will crowd out other sectors of the economy that use the same resources and ignores potential negative health and environmental externalities once development has begun. The potential for negative risks and impacts lies at the heart of the debate about fracking in New York and led to the moratorium (Kaplan 2014).

Data collected by the U.S. Bureau of Labor Statistics (BLS) show that employment in the oil and natural gas industry in Pennsylvania created, on average, roughly 3,000 jobs annually between 2007 and 2012 (Cruz, Smith, and Stanley 2014). Since that data covered oil in addition to natural gas, the estimate represents an upper bound for employment generated within the sector solely from shale development and ignores spillover effects and cross-industry links. However, the estimate is in line with previous academic studies. Weber (2012) used a triple-differenced strategy with data from Colorado, Texas, and Wyoming and found that an additional $1 million in natural gas production generated 2.35 new jobs and increased employment by 1.5 percent. Based on those results, natural gas development created slightly less than 1,400 jobs in the Fayetteville shale in 2007 while an industry-funded study estimated 9,500 jobs. Similarly, for the Marcellus shale, those results imply creation of 2,200 jobs, significantly less than the industry-funded estimate of more than 44,000 for 2009.

Maniloff and Mastromonaco (2014) used a similar difference-in-differences approach at a national level to estimate local economic impacts of shale gas and oil development on employment and earnings by industry. They found, using county-level data for 2000–2010, that counties that had productive shale wells saw 12 percent higher employment and considerable wage growth in tradable sectors after conditioning the data on predevelopment unemployment levels. The authors' estimates suggest that shale gas and oil created approximately 76,000 jobs in Pennsylvania over the eleven-year period, significantly fewer jobs per year than the IO-projected 88,000 jobs for 2010 alone reported in Considine, Watson, and Blumsack (2010).

Other studies that used hedonic pricing methods have suggested that environmental risks associated with shale development negatively impact local areas. Hedonic models rely on an indirect valuation approach that uses observable market transactions to estimate values for associated nonmarket characteristics. Muehlenbachs, Spiller, and Timmins' (2013) study involving housing data for New York and Pennsylvania pointed to the risk of contamination from fracking having a negative effect on property values; the value of homes that relied on ground water was significantly reduced when the homes were located within 1.5 kilometers of a shale well. That estimate is consistent with results from Boxall, Chan, and McMillan (2005), which found a statistically significant, negative relationship between residential property values and the number of wells within 4.0 kilometers in rural areas near Calgary, Canada. Results from Taylor, Phaneuf, and Liu (2012) are also consistent with this pattern. Commercial gas development and associated environmental risks reduced neighboring residential properties' value by 4.5–7.5 percent.

Uncertainty surrounding the benefits and costs associated with shale development in the literature reflects attitudes on the ground. Because of the boom-bust cycle of coal mining in the United States in the 1970s and 1980s, residents in coal regions tend to have reservations about natural gas development and believe that the industry may rapidly grow and just as rapidly decline in the same way coal did (Brasier et al. 2011). Examining the Haynesville shale in Louisiana, Ladd (2013) found that 57 percent of respondents believed that the benefits of gas development outweighed the costs; 31 percent believed that the costs outweighed the benefits. The most frequently mentioned costs were increases in road damage, noise, traffic accidents, and contamination of water resources.

In summary, the development of shale gas appears to have had both positive and negative impacts on local economies during the past decade. Studies using IO models have found large positive benefits in terms of employment, tax revenue, and value added but may not have accurately captured the full impact of the industry due to underlying assumptions used in the models and difficulties valuing environmental costs and risks. Studies based on difference-in-differences and hedonic pricing methods have found that the benefits are much smaller and that the environmental costs of shale gas development are capitalized in housing prices. The considerable uncertainty surrounding new unconventional methods—hydraulic fracturing and horizontal drilling—has produced a wide variety of attitudes toward this development among communities. Some studies have estimated the short-run economic impacts of shale gas development, but because the technology is new, those studies generally have failed to measure long-run economic impacts. This study adds to the existing literature on economic impacts of fracking as the first to use the New York moratorium and the border between Pennsylvania and New York as a naturally occurring experiment.

The Natural Experiment and the Difference-in-differences Methodology

This study employs difference-in-differences (DID) methods to estimate the economic impact of shale gas development using the discontinuity created by New York's 2008 fracking moratorium. Because of the moratorium, counties in the Pennsylvania treatment group are affected by fracking after 2008 and the New York counties serve as a control group by proxying for the counterfactual economy of Pennsylvania without shale extraction. Our baseline model compares changes over time for counties along the New York / Pennsylvania border. We first estimate a DID model that includes a quadratic time trend to relax the constant growth assumption and account for time-varying unobserved heterogeneity common to both states. The quadratic time trend is particularly important since our analysis includes periods of both increasing and decreasing prices for natural gas and the 2007–2009 recession:

$$(1) \quad Y_{ct} = \beta_0 + \beta_1 PA_c + \beta_2 Post2008_t + \beta_3 PA_c{*}Post2008_t + \beta_4 t + \beta_5 t^2 + \varepsilon_{ct}.$$

The dependent variable, Y_{ct}, represents outcomes of interest at the county or zip-code level such as total wages, an industry's wages, total employment, and an industry's employment in a given month, quarter, or year. An indicator for the Pennsylvania counties, PA_c, captures time-invariant differences between the New York and Pennsylvania counties, and an indicator for the post-moratorium period, $Post2008_t$, measures changes in the New York control counties after the moratorium. The coefficient of interest, β_3, is estimated from the interaction between the Pennsylvania treatment indicator and the post-fracking indicator, $PA_c{*}Post2008_t$.

The coefficients of equation 1 allow us to measure changes in the outcome of interest after accounting for quadratic trends in the data. For wages, for example, β_0 measures the average wage in the New York counties before 2008 and β_1 captures the difference between wages in Pennsylvania and New York during that same period. The change in real wages in New York after 2008 is captured by β_2 while β_3 measures the average treatment effect of shale gas development by differencing the changes in wages in the border counties of Pennsylvania after 2008 with changes in wages in the New York counties after 2008.

This type of model, while common in the literature, presents some difficulties when approximating an idealized experiment. The most common concern is the problem of variation of the standard omitted variables: relevant explanatory variables that are not observed but are correlated with the included explanatory variables and may bias the estimates. The indicator for Pennsylvania counties captures any time-invariant differences between the states, and the post-2008 indicator and time trend capture shared time-varying differences. Under this specification, the analysis is vulnerable only to time-varying differences among counties that are not due to shale extraction.

The key underlying assumption of this model is that the outcomes in the treatment and control groups would follow the same time path in the absence of shale development once conditioned on the included trend. However, the model is not properly specified if the rate of growth of either the treatment or the control group changed after the treatment relative to before the treatment. Thus, we expand the analysis to include a model that allows for differential growth rates over time beginning after the New York extraction moratorium in 2008. The baseline model in equation 1 provides a single post-2008 estimate for the impact of shale gas. The new model investigates short-term versus longer-term effects by estimating a model with year effects and interactions for each year after the moratorium was enacted:

$$(2)\quad Y_{ct} = \beta_0 + \beta_1 PA_c + \beta_2 PA2008_{ct} + \beta_3 PA2009_{ct} + \beta_4 PA2010_{ct} + \beta_5 PA2011_{ct} + \beta_6 PA2012_{ct} + \beta_7 PA2013_{ct} + \beta_8 2008_t + \beta_9 2009_t + \beta_{10} 2010_t + \beta_{11} 2011_t + \beta_{12} 2012_t + \beta_{13} 2013_t + \beta_{14} t + \beta_{15} t^2 + \varepsilon_{ct}.$$

This specification decomposes the single post-2008 estimate from equation 1 into estimated effects for each of the six post-moratorium years. The coefficients of interest are β_2 through β_7, which measure the impacts of shale development in Pennsylvania for 2008 through 2013 relative to economic development in the New York counties during the same period, allowing us to distinguish immediate benefits from changes that accrue gradually after a period of years.

This distinction is particularly important given the ambiguity surrounding the duration of the moratorium, when it was implemented, and variation in the level of drilling activity in Pennsylvania between 2008 and 2013, which is shown in Figure 1.[1]

The control counties in New York allow us to estimate how several economic characteristics of the counties in Pennsylvania would have changed in the absence of shale gas development. The initial baseline approach is indifferent to spillovers and the locations of drilling sites; it compares nine Pennsylvania border counties with ten New York border counties,[2] which are identified in Figure 2.

Because the focus of our analysis is based on more refined definitions of the treatment and controls, we limit our analysis to the Pennsylvania border counties in which significant shale gas activity occurred during the study period—Tioga, Bradford, and Susquehanna (see Figure 2)—and define two sets of New York control counties.[3] The first set is comprised of nine New York counties: Stueben, Chemung, Tioga, and Broome, which are adjacent to the actively drilled counties in Pennsylvania, and Yates, Schuyler, Tompkins, Cortland, and Chenango just to the north as a second layer. The second set uses only the five northerly nonborder counties in New York to account for any spillover from Pennsylvania into New York. These northern counties are unlikely to be influenced by local economic changes caused by shale development, such as cross-state labor supplies, spending patterns, and interstate travel. As a further robustness check to account for possible spillover effects, we use zip-code-level data to estimate impacts of shale development in bands of 50 and 100 kilometers from the border.

Data

We use monthly, quarterly, and annual data from the U.S. Census Bureau, Bureau of Economic Analysis (BEA), and BLS to quantify the local impacts of shale development for 2001–2013. We begin by analyzing monthly employment data and quarterly wage data from the BLS's quarterly census of employment and wages for all industries and establishments and for four distinct industries: natural resources and mining, manufacturing, construction, and real estate. We define the natural resource and mining industry as an aggregate of the agriculture, forestry, fishing, and hunting industries under North American Industry Classification System (NAICS) code 11 and the mining, quarrying, and oil and gas extraction industries under code 21. Code 11 covers establishments that grow crops, raise animals, and harvest timber, fish, or animals; code 21 covers both the extracting entities and establishments that support such activities.

---

1 We thank an anonymous referee for noting that, when the original moratorium was passed in 2008, gas development firms had already been active in New York conducting preparatory work and may not have immediately pulled their operations due to ambiguity in how long the moratorium would last.

2 The ten New York counties are Chautauqua, Cattaraugus, Allegany, Steuben, Chemung, Tioga, Broome, Delaware, Sullivan, and Orange. The nine border counties in Pennsylvania are Erie, Warren, McKean, Potter, Tioga, Bradford, Susquehanna, Wayne, and Pike.

3 We thank an anonymous reviewer and participants at the 2014 Northeastern Agricultural and Resource Economics Association workshop for the suggestion to focus on the Pennsylvania counties that had a large amount of shale gas development.

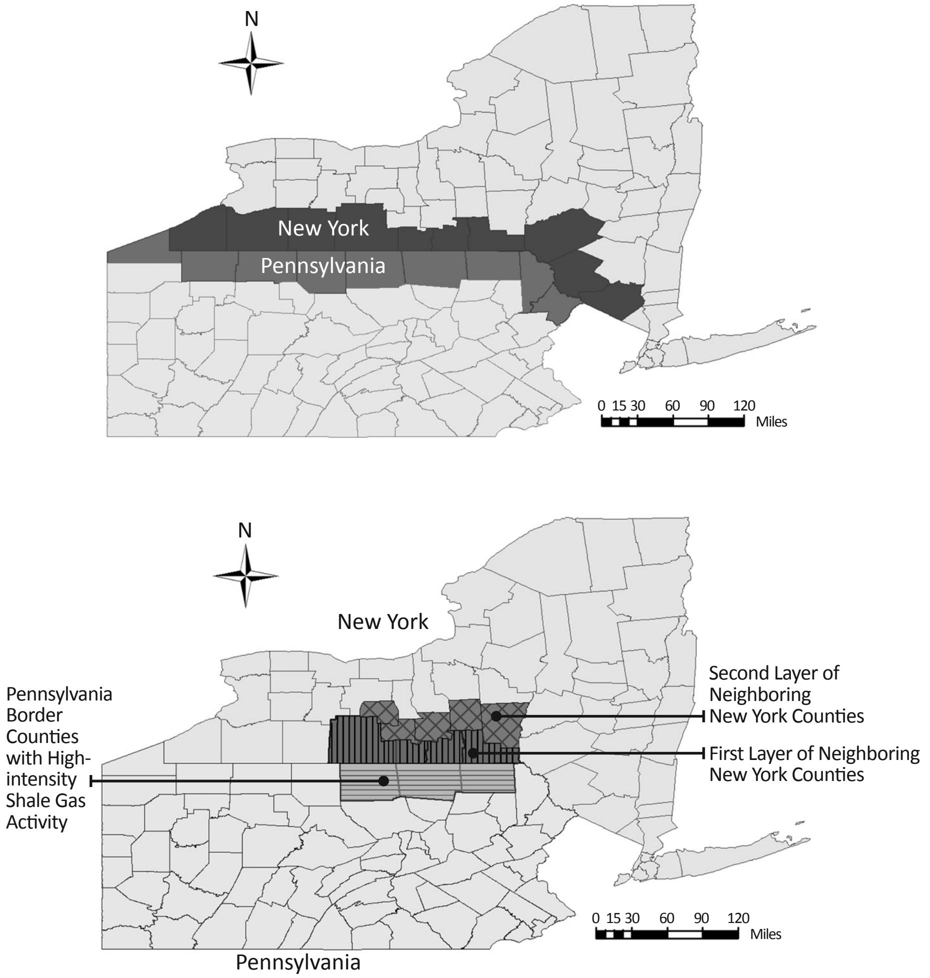

Figure 2. Border Counties in New York and Pennsylvania

While data from the mining sector could provide a more focused representation of shale gas activity, much of the monthly and quarterly data of interest did not meet BLS or state agency disclosure standards and consequently could not be used for this analysis. Therefore, the natural resource and mining industry provides the most disaggregated data that are more accurate and are reported more often. At the same time, however, combining the two industry data sets may mask changes at an industry level. Therefore, we verify the robustness of these estimates using additional data from the U.S. Census Bureau's zip-code-based business pattern data.

As previously noted, some prior studies found that extraction of shale gas has broad impacts on supporting and interlinked industries. We focus on changes in the construction, manufacturing, and real estate sectors as a complement to the analysis of impacts on overall economic activity and the mining sector. Construction (code 23) is a closely related industry since development of drilling infrastructures and wells requires supporting activities such as pouring of concrete. Manufacturing (codes 31–33) is relevant when we examine cross-industry spillovers noted in prior work on boom-bust cycles and resource extraction (e.g., Jacobsen and Parker 2014, Maniloff and Mastromonaco 2014), including potential reallocations of labor from manufacturing to mining-related jobs. The real estate and rental category (code 53) allows us to compare our results with those of studies that measured the impacts of gas development through hedonic pricing models using real estate transactions. In addition, real estate and rentals can be considered as a supporting industry since leases of land for drilling are real estate transactions. Along with mining, these three additional sectors are subject to some of the greatest estimated impacts of gas development in prior studies that were based on gross output and value added (e.g., Considine, Watson, and Blumsack 2010).[4]

In addition to the BLS county-level data, we use annual county- and zip-code-level statistics from the Census Bureau's county and zip-code business pattern databases on industry-level payrolls and employment for 2004 through 2011 to strengthen the analysis. The zip-code-level analysis allows us to refine our definitions of control and treatment locations based on distance from the New York / Pennsylvania border. We use ArcGIS to calculate distances from the border to the center of each zip code in New York and Pennsylvania and estimate the economic impacts of shale gas development at 50 kilometers (31 miles) and 100 kilometers (62 miles). This strategy allows us to obtain results that are less likely to have been influenced by cross-border spillovers from Pennsylvania into New York.

Results and Discussion

We present the results from the DID specifications for the BLS county-level data in Tables 1–6. Tables 1 and 2 present wage and employment results for the full set of counties, the high-intensity shale-development counties in Pennsylvania with both layers of New York counties as controls, and the high-intensity Pennsylvania counties with the nonborder layer of New York counties as a control. Table 1 presents the results from equation 1, in which time trends are used to examine quarterly wages and monthly employment. We find no statistically significant change after 2008 in employment or total wages across all industries for the Pennsylvania counties relative to the New York counties. These results suggest that shale gas development does not have a significant impact over the entire local economy in terms of increasing total wages or employment.

Table 2 presents the results from equation 2, which includes year fixed effects and interactions that capture short-term versus longer-term changes after 2008. We find, based on the insignificant coefficients on the interaction terms, that shale gas development never causes a statistically significant change in predicted total wages or employment in Pennsylvania compared to New York between 2008 and 2013.

For the analyses of industry-specific outcomes, we restrict our Pennsylvania sample to the three high-intensity counties as this presents the most likely scenario for identifying the impacts of shale gas development on the local

---

[4] While additional sectors may be worth describing, we believe that these four, when combined with an examination of total economic activity at the county level, can provide an accurate picture of local changes due to gas development. Examining additional subindustries is a natural next step for future work.

Table 1. Difference-in-differences Results: Total Wages and Employment

		High-intensity Pennsylvania Counties Versus	
Variable	**All Border Counties**	**Both NY Layers**	**Nonborder NY Layer**
Total Wages ($1,000)			
Pennsylvania	−115,199.8***	−127,295.3**	−41,898.2***
(20,695.4)	(12,668.45)	(12,486.6)	
Post-2008	1,386.8	2,565.171	−2,612.3
(37,872.9)	(30,902.75)	(29,236.5)	
Interaction	−16,268.7	−9,037.444	−3,059.6
(33,895.1)	(20,197.21)	(20,915.5)	
Observations	950	624	416
Total Employees			
Pennsylvania	−13,151.5***	−12,874.44**	−3,213.5***
(1,522.8)	(864.3573)	(765.9)	
Post-2008	−820.4	−421.4048	−479.6
(2,507.8)	(1,897.1)	(1,566.9)	
Interaction	225.1	833.267	−59.52
(2,278.2)	(1,242.178)	(1,136.1)	
Observations	2,850	1,872	1,248

Notes: Robust standard errors are reported within parentheses. Estimates are from a model of the form defined in equation 1 including a quadratic time trend. Time trend coefficients are available upon request. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

economy. Tables 3 and 4 present the DID results for industry wages and Tables 5 and 6 present the DID results for employment.

When we compare the three high-intensity counties in Pennsylvania with both of the New York control layers, we find that the only industry that was significantly affected by shale gas development is natural resources and mining. In that industry, local industry wages in Pennsylvania increased by $7 million at the county level relative to wages in the New York counties (see Table 3). When we compare the high-intensity Pennsylvania counties with only nonborder New York counties, the relative increase is somewhat larger at $7.5 million and estimated wages in the construction industry increase by $2.2 million at the county level. The fact that the effect on the construction industry is absent when we include the adjoining New York counties points to spillover benefits for the New York border counties from shale development in Pennsylvania. We also find imprecisely estimated decreases in manufacturing wages and increases in real estate wages in the Pennsylvania counties relative to the nonborder New York counties; these results are not robust to inclusion of year fixed effects (shown in Table 4).

Table 4 presents the wage results from equation 2, which includes year fixed effects and interactions by industry. These results mirror the ones presented in Table 3 but demonstrate that the statistically significant benefits found for Pennsylvania first appear in 2010. When comparing the counties in Pennsylvania with both layers of neighboring counties in New York, we find that shale gas development does not cause a statistically significant change in the construction, manufacturing, and real estate industries. However, natural resource and mining industry wages in the Pennsylvania counties increase by $5.3 million in 2010, $10.7 million in 2011, $13.0 million in 2012, and $13.9 million in 2013. The magnitudes of the effects are larger when compared to the nonborder New York counties—$5.9 million in 2010, $11.7 million in 2011, $14.0 million in 2012, and $14.8 million in 2013. Once again, we also find a significant increase in construction wages—$3.8 million in 2011, $4.0 million in 2012, and $5.1 million in 2013. These results indicate that there are spillover effects on the New York / Pennsylvania border.

Table 2. Difference-in-differences Results with Year Fixed Effects: Total Wages and Employment

		High-intensity Pennsylvania Counties Versus	
Variable	**All Border Counties**	**Both NY Layers**	**Nonborder NY Layer**
	Total Wages ($1,000)		
PA	–115,199.8*** (20,801.7)	–127,295.3*** (12,778.2)	–41,898.2*** (12,644.2)
PA 2008	–24,448.5 (66,257.9)	–29,028.5 (40,018.9)	–16,735.2 (41,459.1)
PA 2009	–20,198.5 (63,578.8)	–20,109.3 (38,824.7)	–16,775.2 (41,506.6)
PA 2010	–20,643.3 (64,478.6)	–12,507.5 (39,995.7)	–7,002.8 (42,288.7)
PA 2011	–10,571.0 (68108.9)	443.5 (41,214.3)	6,955.5 (43,611.2)
PA 2012	–7,989.8 (69,373.8)	5,084.3 (42,445.8)	9,121.5 (45,733.8)
PA 2013	–11,254.0 (94,506.9)	1,892.7 (42,107.7)	6,078.4 (45,631.3)
Observations	950	624	416
	Total Employees		
PA	–13,151.5*** (1,525.5)	–12,874.4*** (866.8)	–3,213.5*** (769.0)
PA 2008	–620.6 (4,356.3)	–717.4 (2,400.2)	–876.5 (2,202.2)
PA 2009	–183.0 (4,184.6)	–44.14 (2,327.9)	–782.7 (2,155.4)
PA 2010	204.1 (4,183.0)	818.9 (2,346.4)	–124.9 (2,193.3)
PA 2011	698.4 (4,270.5)	1,591.5 (2,348.4)	536.4 (2,201.2)
PA 2012	813.6 (4,309.2)	1,777.0 (2,359.6)	608.9 (2,229.1)
PA 2013	650.7 (5,849.4)	1,573.8 (2,337.4)	281.5 (2,222.8)
Observations	2,850	1,872	1,248

Notes: Robust standard errors are reported within parentheses. Estimates are from a model of the form defined in equation 2. Coefficients on the non-interacted year effects and time trends are available upon request. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 3. Difference-in-differences Results for Wages by Industry

	Construction	Manufacturing	Natural Resources and Mining	Real Estate
Wages ($1,000) for High-intensity Pennsylvania Counties versus Both New York Layers				
PA	−6,186.8***	−28,024.5***	75.89	−5,280.5***
	(676.9)	(3,787.9)	(187.1)	(1,012.6)
Post-2008	−360.0	2,944.1	−2,633.9***	−2,223.1
	(1,874.3)	(7,224.4)	(606.6)	(2,878.5)
Interaction	1,220.3	−4,874.9	6,939.3***	3,785.7
	(1,215.3)	(5,292.8)	(968.3)	(2,724.2)
Observations	624	624	619	155
Wages ($1,000) for High-intensity Pennsylvania Counties versus Nonborder New York Layer				
PA	−1,242.1***	4,892.8*	−283.5	−2,782.1***
	(222.0)	(2,721.2)	(268.4)	(1,010.5)
Post-2008	−1,478.3**	862.2	−4,170.3***	−3,348.3
	(586.5)	(3,783.3)	(904.3)	(2,726.9)
Interaction	2,196.2***	−7,373.0*	7,460.9***	4,648.5*
	(543.5)	(4,007.5)	(986.0)	(2,666.7)
Observations	416	416	411	103

Notes: Robust standard errors are reported within parentheses. Estimates are from a model of the form defined in equation 1 including a quadratic time trend. Time trend coefficients are available upon request. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 4. Difference-in-differences Results for Wages with Year Fixed Effects by Industry

	Construction	Manufacturing	Natural Resources and Mining	Real Estate
Wages ($1,000) for High-intensity Pennsylvania Counties versus Both New York Layers				
PA	−6,186.8***	−28,024.5***	75.89	−5,280.5***
	(688.0)	(3,818.3)	(187.0)	(1,047.3)
PA 2008	−1,299.8	−7,969.7	−388.9	−1,001.0
	(2,219.9)	(11,125.8)	(571.5)	(3,285.7)
PA 2009	−1,444.8	−6,004.9	−375.9	−1,135.8
	(2,357.6)	(10,419.3)	(581.0)	(3,075.6)
PA 2010	−49.50	−3,078.7	5,260.0***	−1,381.7
	(2,428.0)	(9,836.6)	(1,550.2)	(3,503.1)
PA 2011	2,812.7	−4,074.0	10,723.4***	6,778.6
	(2,541.2)	(9,568.0)	(2,115.7)	(5,012.6)
PA 2012	3,082.7	−3,890.5	12,950.3***	11,109.7
	(2,707.2)	(9,302.5)	(2,958.0)	(9,827.3)
PA 2013	4,220.5	−4,231.9	13,872.7***	8,241.7
	(2,803.7)	(8,937.2)	(2,425.5)	(7,737.1)
Observations	624	624	619	155

Continued on following page

Table 4. Difference-in-differences Results for Wages with Year Fixed Effects by Industry (continued)

	Construction	Manufacturing	Natural Resources and Mining	Real Estate
Wages ($1,000) for High-intensity Pennsylvania Counties versus Nonborder New York Layer				
PA	–1,242.1***	4,892.8*	–283.5	–2,782.1**
	(230.3)	(2,755.6)	(268.6)	(1,063.6)
PA 2008	–199.7	–3,269.0	–304.5	–341.2
	(709.2)	(7,988.5)	(827.6)	(2,938.0)
PA 2009	–228.0	–4,823.4	–213.8	–721.9
	(680.9)	(7,668.1)	(818.7)	(2,920.8)
PA 2010	647.4	–5,150.2	5,852.7***	–1,161.5
	(983.6)	(7,469.6)	(1,650.3)	(3,587.4)
PA 2011	3,831.2***	–7,709.0	11,682.3***	7,497.5
	(1,159.4)	(7,500.8)	(2,167.7)	(4,942.3)
PA 2012	3,966.1***	–10,437.6	14,071.3***	12,564.9
	(1,396.0)	(7,861.9)	(2,989.3)	(9,860.7)
PA 2013	5,160.4***	–12,848.7	14,785.3***	9,713.3
	(1,605.5)	(8,045.9)	(2,491.5)	(7,613.5)
Observations	416	416	411	103

Notes: Robust standard errors are reported within parentheses. Estimates are from a model of the form defined in equation 2. Coefficients on the non-interacted year effects and time trends are available upon request. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 5. Difference-in-differences Results for Employment by Industry

	Construction	Manufacturing	Natural Resources and Mining	Real Estate
Total Employees for High-intensity Pennsylvania Counties versus Both New York Layers				
PA	–549.1***	–1,518.0***	50.51***	–219.7***
	(38.06)	(189.9)	(12.04)	(40.94)
Post-2008	–48.54	76.18	–122.6***	–50.00
	(90.30)	(299.3)	(22.09)	(97.10)
Interaction	135.6**	–156.0	307.6***	76.78
	(57.36)	(245.8)	(30.34)	(69.30)
Observations	1,872	1,872	1,857	155
Total Employees for High-intensity Pennsylvania Counties versus Nonborder New York Layer				
PA	–66.04***	989.3***	18.89	–112.8***
	(14.51)	(148.7)	(15.88)	(38.73)
Post-2008	–103.9***	131.4	–196.7***	–64.67
	(28.68)	(172.9)	(32.87)	(80.78)
Interaction	124.7***	–733.4***	329.8***	79.96
	(24.53)	(198.0)	(33.17)	(63.52)
Observations	1,248	1,248	1,233	103

Notes: Robust standard errors are reported within parentheses. Estimates are from a model of the form defined in equation 1 including a quadratic time trend. Time trend coefficients are available upon request. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 5 reports the results of equation 1 for employment by industry, which reflect corresponding job growth along with the wage increases shown in Table 4. We find no statistically significant change in employment in the manufacturing and real estate industries in Pennsylvania, but construction industry employment increases by 136 workers and natural resource and mining industry employment increases by 308 workers when we use both of the New York layers. The results from comparing Pennsylvania to the nonborder New York counties are similar. These results highlight a marked

Table 6. Difference-in-differences Results for Employment by Industry with Year Fixed Effects

	Construction	Manufacturing	Natural Resources and Mining	Real Estate
Total Employees for High-intensity Pennsylvania Counties versus Both New York Layers				
PA	−549.1***	−1,518.0***	50.51***	−219.7***
	(38.26)	(190.4)	(12.06)	(42.40)
PA 2008	−25.92	−366.3	−23.27	−7.635
	(108.0)	(488.8)	(33.42)	(117.8)
PA 2009	−1.007	−236.7	−58.86*	1.143
	(107.8)	(451.2)	(31.25)	(108.5)
PA 2010	86.72	20.57	229.8***	−9.510
	(112.3)	(432.5)	(55.60)	(121.2)
PA 2011	204.7*	−125.3	521.2***	133.3
	(110.7)	(408.6)	(74.20)	(128.6)
PA 2012	232.6**	−124.1	590.1***	196.4
	(111.9)	(394.3)	(79.70)	(190.7)
PA 2013	316.7***	−104.3	604.3***	144.5
	(113.4)	(381.2)	(60.52)	(166.5)
Observations	1,872	1,872	1,857	155
Total Employees for High-intensity Pennsylvania Counties versus Nonborder New York Layer				
PA	−66.04***	989.3***	18.89	−112.8***
	(14.67)	(149.3)	(15.91)	(40.88)
PA 2008	0.844	−398.2	−19.80	−1.171
	(39.66)	(382.6)	(43.41)	(102.7)
PA 2009	−2.006	−512.0	−49.38	−2.838
	(39.72)	(351.4)	(41.46)	(98.31)
PA 2010	67.82	−517.7	255.4***	−23.25
	(52.58)	(347.8)	(61.18)	(112.6)
PA 2011	193.9***	−809.5**	561.2***	130.5
	(50.80)	(337.3)	(78.30)	(117.0)
PA 2012	202.7***	−1,004.9***	639.6***	211.6
	(50.60)	(343.0)	(83.56)	(178.7)
PA 2013	284.8***	−1,158.0***	639.6***	156.5
	(56.34)	(350.9)	(68.26)	(150.5)
Observations	1,248	1,248	1,233	103

Notes: Robust standard errors are reported within parentheses. Estimates are from a model of the form defined in equation 2. Coefficients on the non-interacted year effects and time trends are available upon request. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 7. Zip-code-level Difference-in-differences Results

	Annual Payroll ($1,000)			Employees			Establishments		
	All	**50 km or Less**	**50–100 km**	**All**	**50 km or Less**	**50–100 km**	**All**	**50 km or Less**	**50–100 km**
Results from Equation 1 – With Distance Bands									
PA	−40,935.3***	−55,011.7***	−14,718.6***	−1,267.7***	−1,672.3***	−516.7**	−37.29***	−75.51***	−62.49***
	(6,685.5)	(9,479.9)	(5,581.4)	(222.6)	(313.4)	(202.6)	(11.40)	(12.94)	(9.761)
Post-2008	2,704.3	3,577.6	1,227.0	99.05	103.9	50.13	−2.514	−0.217	−0.659
	(15,789.1)	(20,994.1)	(10,796.3)	(505.3)	(667.5)	(374.0)	(19.40)	(25.46)	(20.07)
Interaction	−5,320.1	−6,214.0	−3,067.1	−121.5	−99.11	−111.7	2.685	−0.378	0.692
	(10,431.8)	(14,758.3)	(8,761.7)	(328.8)	(457.8)	(306.4)	(15.92)	(18.52)	(13.92)
Observations	1,485	1,146	847	1,413	1,089	791	941	1,292	1,668
Results from Equation 2 – With Distance Bands and Year Fixed Effects									
PA	−40,933.0***	−55,012.6***	−14,715.1***	−1,265.2***	−1,669.3***	−515.0**	−37.29***	−75.51***	−62.49***
	(6,697.3)	(9,502.4)	(5,599.9)	(222.9)	(314.0)	(203.4)	(11.44)	(12.97)	(9.779)
PA 2008	−7,581.9	−9,491.8	−3,770.7	−176.0	−237.2	−55.19	1.494	−1.255	−0.319
	(17,327.4)	(24,634.2)	(14,377.2)	(547.9)	(772.6)	(488.1)	(25.46)	(29.49)	(22.17)
PA 2009	−5,152.1	−5,650.2	−3,636.7	−150.3	−130.2	−132.7	1.634	−0.641	0.134
	(16,908.4)	(23,954.8)	(14,179.2)	(533.6)	(739.6)	(500.8)	(25.00)	(29.42)	(22.07)
PA 2010	−5,440.7	−6,340.4	−3,161.4	−72.68	−27.97	−94.69	3.017	−0.0377	1.003
	(17,499.4)	(24,800.3)	(14,590.5)	(518.2)	(715.8)	(488.7)	(24.81)	(29.50)	(22.08)
PA 2011	−3,190.6	−3,483.7	−1,714.6	−100.2	−22.57	−170.2	4.588	0.419	1.945
	(17,773.3)	(24,930.2)	(15,456.7)	(536.6)	(731.8)	(538.1)	(24.95)	(29.82)	(22.32)
Observations	1,485	1,146	847	1,413	1,089	791	941	1,292	1,668

Notes: **All:** Zip codes in high-intensity Pennsylvania counties versus zip codes in both New York layers. **50 kilometers or less**: Zip codes in high-intensity Pennsylvania counties versus neighboring New York zip codes within 50 kilometers (≈ 30 miles) of the border. **50–100 kilometers**: Zip codes in high-intensity Pennsylvania counties versus neighboring New York zip codes between 50 and 100 kilometers (≈ 30–60 miles) of the border. Standard errors are shown in parentheses. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

decrease in manufacturing employment, suggesting a reallocation of workers from manufacturing to mining sectors as gas development ramped up.

Table 6 shows the results of equation 2 for employment by industry, which incorporate year fixed effects and interactions by industry. When comparing the Pennsylvania counties to both layers of neighboring counties in New York, we find no statistically significant short-term economic effects on employment in manufacturing and real estate and no change in construction employment from 2008 to 2010. After 2010, construction employment increases by 204 workers in 2011, 232 workers in 2012, and 317 workers in 2013. After a two-year delay, employment in natural resources and mining increases by 230 in 2010, 521 in 2011, 590 in 2012, and 607 in 2013. We see a similar effect for wages in construction and natural resources and mining when we use only the nonborder New York counties. In addition, we find that the statistically significant decrease in manufacturing employment in Pennsylvania began in 2011 and got somewhat larger in 2012 and 2013.

We test the robustness of our results by replicating the analysis at the zip-code level using the U.S. Census Bureau's zip-code business pattern data for 2004 through 2011 and present the results in Table 7. Equation 1 includes a single post-moratorium effect while equation 2 generates year-by-year estimates. We compare total annual payroll, employees, and number of establishments across all of the zip codes in the high-intensity Pennsylvania counties with zip codes in two distance bands for neighboring New York counties: zip codes within 50 kilometers (approximately 30 miles) of the state border and zip codes within 50 to 100 kilometers of the border.

We find no significant increase in total annual payroll, employment, or establishments at the zip-code level in the high-intensity Pennsylvania counties due to shale gas development when compared to zip codes within both of the New York distance bands. This lack of significance remains when we use equation 2, which incorporates year effects. Thus, shale gas development in the Pennsylvania counties does not cause a statistically significant change in annual payroll, employment, or number of establishments between 2008 and 2011 at a zip-code level relative to the New York counties regardless of how far the New York counties are from the border. These results are similar to the ones shown in Tables 1 and 2 for the total county employment and wage measures.

We perform further robustness checks of the results using the U.S. Census Bureau's business pattern data at a county level and personal income and employment data from the U.S. Bureau of Economic Analysis.[5] Once again, we find no statistically significant change in annual payroll, employment, or number of establishments in response to shale gas development.

Conclusions

Direct economic benefits of shale gas extraction have been presented as a reason to support its continued development. However, there is no consensus regarding what the broader economic impacts from shale gas extraction are. Previous estimates that were based on input-output models relied on troubling assumptions and ignored offsetting environmental and health costs associated with fracking while estimates generated with hedonic pricing models fail to capture all potential economic benefits for communities and often ignore

[5] These results are available from the corresponding author by request.

complexities related to types of sales by not controlling for ownership of mineral rights.

We use the border between Pennsylvania and New York and New York's 2008 moratorium on fracking as a naturally occurring experiment to study the economic impacts of shale extraction using a difference-in-differences analysis. We find that shale gas development significantly increases employment and wages in the construction and natural resource and mining industries but not in the entire economy at a county level. We find no statistically significant change in employment, earnings, or per capita personal income at a zip-code level and a reduction in employment in the manufacturing sector.

Results of models that disaggregated the effects by year suggest that the benefits of shale gas development did not occur until about 2010, two years after intensive production commenced in Pennsylvania. Our estimates suggest that Pennsylvania experienced a shale gas boom relative to neighboring counties in New York beginning in 2011; employment and wages in the natural resource and mining industry in Pennsylvania grew approximately 40 percent annually from 2010 to 2013. This lag in the identified economic benefits may be related to shale gas activities (other than drilling and extraction) in New York that continued after the 2008 moratorium.

We find that shale gas development in Pennsylvania is not leading to broader economic growth (captured as total employment and wages in Pennsylvania) and is associated with potentially offsetting reductions in manufacturing employment. This lack of movement in aggregate economic measures may stem in part from the relatively small share of the local economy represented by the mining industry. Prior to development of the Marcellus shale, the natural resource and mining industry accounted for just 2 percent of total employment and wages in the Pennsylvania counties bordering New York. After development of the Marcellus, the industry still accounts for only 4 percent of total employment and wages in those counties.

Further work is needed to understand how the economic impacts of gas development are influenced by conditions such as pre-existing slack in labor markets, which may determine the relative supply of workers able to join an expanding gas industry, development of the region's infrastructure,[6] the relative size of the natural resource and mining industry in an area, the extraction infrastructure required by specific shale deposits, and attitudes of community members. Moreover, while a fracking boom may increase mining and construction employment in the short run, it also could expose communities to the effects of a later bust similar to those experienced in coal communities in the 1980s (Weinstein 2014). Our results serve as a cautionary note to policymakers considering the potential benefits of shale gas development.

References

Barth, J.M. 2013. "The Economic Impact of Shale Gas Development on State and Local Economies: Benefits, Costs, and Uncertainties." *New Solutions* 23(1): 85–101.

Black, D., T. McKinnish, and S. Sanders. 2005. "The Economic Impact of the Coal Boom and Bust." *The Economic Journal* 115(503): 449–476.

[6] In North Dakota, the rapid production in the Bakken shale may lead to faster economic growth there than in areas with more developed infrastructures such as the Barnett shale in Texas.

Boxall, P.C., W.H. Chan, and M.L. McMillan. 2005. "The Impact of Oil and Natural Gas Facilities on Rural Residential Property Values: A Spatial Hedonic Analysis." *Resource and Energy Economics* 27(3): 248–269.
Brasier, K.J., M.R. Filteau, D.K. McLaughlin, J. Jacquet, R.C. Stedman, T.W. Kelsey, and S.J. Goetz. 2011. "Residents' Perceptions of Community and Environmental Impacts from Development of Natural Gas in the Marcellus Shale: A Comparison of Pennsylvania and New York Cases." *Journal of Rural Social Sciences* 26(1): 32–61.
Center for Business and Economic Research. 2008. "Projecting the Economic Impact of the Fayetteville Shale Play for 2008–2012." Working paper, College of Business, University of Arkansas, Fayetteville.
Considine, T.J., R. Watson, and S. Blumsack. 2010. "The Economic Impacts of the Pennsylvania Marcellus Shale Natural Gas Play: An Update." Working paper, College of Earth and Mineral Sciences, Pennsylvania State University.
Cruz, J., P.W. Smith, and S. Stanley. 2014. "The Marcellus Shale Gas Boom in Pennsylvania: Employment and Wage Trends." *Monthly Labor Review*, U.S. Bureau of Labor Statistics, Washington, DC.
Energy Information Administration. 2004. "Natural Gas Withdrawals from Shale Gas in Pennsylvania." U.S. Department of Energy, Washington, DC. Available at www.eia.gov/dnav/ng/hist/ngm_epg0_fgs_spa_mmcfm.htm (accessed February 2, 2015).
———. 2012. "Annual Energy Outlook 2012." U.S. Department of Energy, Washington, DC.
———. 2013. "Annual Energy Outlook 2013." U.S. Department of Energy, Washington, DC.
Higginbotham, A., A. Pellillo, T. Gurley-Calvez, and T.S. Witt. 2010. "The Economic Impact of the Natural Gas Industry and the Marcellus Shale Development in West Virginia in 2009." Bureau of Business and Economic Research, College of Business and Economics, West Virginia University.
Howarth, R.W., A. Ingraffea, and T. Engelder. 2011. "Natural Gas: Should Fracking Stop?" *Nature* 477(7364): 271–275.
IHS. 2012. "America's New Energy Future: The Unconventional Oil and Gas Revolution and the U.S. Economy." IHS, Washington, DC. Available at http://press.ihs.com/press-release/economics/us-unconventional-oil-and-gas-revolution-increase-disposable-income-more-270 (accessed February 28, 2015).
Jacobsen, G., and D. Parker. 2014. "The Economic Aftermath of Resource Booms: Evidence from Boomtowns in the American West." *Economic Journal* doi 10.1111/ecoj.12173.
Jacquet, J.B. 2012. "Landowner Attitudes toward Natural Gas and Wind Farm Development in Northern Pennsylvania." *Energy Policy* 50: 677–688.
Kaplan, T. 2014. "Citing Health Risks, Cuomo Bans Fracking in New York State." *New York Times*, December 18. Available at www.nytimes.com/2014/12/18/nyregion/cuomo-to-ban-fracking-in-new-york-state-citing-health-risks.html (accessed February 20, 2015).
Kelsey, T.W., M. Shields, J.R. Ladlee, and M. Ward. 2011. "Economic Impacts of Marcellus Shale in Pennsylvania: Employment and Income in 2009." Marcellus Shale Education and Training Center, Penn State Extension and Penn College, Williamsport, PA.
Kinnaman, T.C. 2011. "The Economic Impact of Shale Gas Extraction: A Review of Existing Studies." *Ecological Economics* 70(7): 1243–1249.
Ladd, A.E. 2013. "Stakeholder Perceptions of Socio-environmental Impacts from Unconventional Natural Gas Development and Hydraulic Fracturing in the Haynesville Shale." *Journal of Rural Social Sciences* 28(2): 56–89.
Maniloff, P., and R. Mastromonaco. 2014 "The Local Economic Impacts of Unconventional Shale Development." Working paper, Colorado School of Mines and University of Oregon.
Mauro, F., M. Wood, M. Mattingly, M. Price, S. Herzenberg, and S. Ward. 2013. "Exaggerating the Employment Impacts of Shale Drilling: How and Why." Multi-state Shale Research Collaborative, Harrisburg, PA.
Muehlenbachs, L., E. Spiller, and C. Timmins. 2013. "The Housing Market Impacts of Shale Gas Development." RFF Discussion Paper 13–39, Resources for the Future, Washington, DC. Available at www.rff.org/RFF/Documents/RFF-DP-13-39.pdf.
Pennsylvania Department of Environmental Protection. 2015. "Natural Gas Wells Drilled by County." DEP, Harrisburg, PA. Available at www.depreportingservices.state.pa.us/ReportServer/Pages/ReportViewer.aspx?/Oil_Gas/Wells_Drilled_By_County (accessed February 2, 2015).
PricewaterhouseCoopers LLP. 2013. "Economic Impact Analysis of the Coal Mining Industry in British Columbia, 2011." Coal Association of Canada, Calgary, Alberta, Canada.
Stimson, R.J., R.R. Stough, and B.H. Roberts. 2006. *Regional Economic Development: Analysis*

and Planning Strategy (2nd edition). New York, NY: Springer.

Taylor, L.O., D.J. Phaneuf, and X. Liu. 2012. "Disentangling the Impacts of Environmental Contamination from Locally Undesirable Land Uses." Unpublished manuscript.

Weber, J.G. 2012. "The Effects of a Natural Gas Boom on Employment and Income in Colorado, Texas, and Wyoming." *Energy Economics* 34(5): 1580–1588.

Weinstein, A.L. 2014. "Local Labor Market Restructuring in the Shale Boom." *Journal of Regional Analysis and Policy* 44(1): 71–92.

Wooldridge, J.M. 2012. *Introductory Econometrics: A Modern Approach* (5th edition). Mason, OH: South-Western.