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Abstract

In the United States, the rapid increase in shale gas production has recently stimulated local economies. This paper investigates the regional economic impact of shale gas development. The border of New York and Pennsylvania provides a natural experiment for its economic impact because of the moratorium on fracking in NY and the supportive fracking regulations in PA. Using BLS data from 2001-2013, results show that shale gas development has a statistically significant impact at the industry level, but not across the entire economy. The findings contribute new evidence to the economic benefits and the boom-bust cycle of shale gas extraction.

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

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Introduction

Over the past decade, the technological advancements of hydraulic fracturing and horizontal drilling have led to the economic feasibility and rapid growth in natural gas production. Hydraulic fracturing or "fracking" is the process of injecting pressurized fluids that creates a network of cracks in rock formations at 5,000 to 10,0000 feet below the Earth's surface. These cracks allow trapped natural gas in underground shale formations to release and flow into the wells at the surface. Over 99% of the fracking fluids is water, while the remainder is a combination of sand and chemicals (Higginbotham et al. 2010). The pressurized fluids create a network of fractures that allow trapped natural gas in underground shale formations to release and flow into the wells. Natural gas is produced from unconventional methods that use a combination of hydraulic fracturing and horizontal drilling or the conventional methods that use vertical drilling.

In the United States, the evolving natural gas markets will increase the consumption of natural gas for electricity and allow the U.S. to become a net export of natural gas by 2019 (EIA 2013). Over half of the US natural gas production comes from unconventional gas resources such as deep gas, tight gas, shale, coalbed methane, and geopressurized zones (Jacquet 2012). Between 2000 and 2009, approximately 190,000 conventional and unconventional natural gas wells have been drilled in the US (Jacquet 2012). Shale gas production is expected to grow from 7.85 trillion cubic feet in 2011 to 16.70 trillion cubic feet in 2014 at an annual growth rate of 2.6% (EIA 2013). At this rate, shale gas will provide the largest source of growth in the domestic supply of natural gas (EIA 2013).

The Marcellus Shale covers 95,000 square miles and spans across four states: Ohio, West Virginia, New York, and Pennsylvania. Over 350 million years ago in the Devonian, the sedimentary rock formation developed along the eastern coast of the US. The thicker layers of the Marcellus formation consist of coarser grained sandstone, siltstone, and shale; the thinner layers consist of finer grained black and gray shale (Higginbotham et al. 2010). The low permeability and deeper depths of shale formations decreases the ability of natural gas to escape from conventional methods; thus, unconventional methods increase the probability of releasing and capturing the trapped gas (Higginbotham et al. 2010).

The introduction of fracking and horizontal techniques transformed the energy potential of the Marcellus Shale in the Appalachian Basin. In 2003, the first natural gas well of the Marcellus was drilled in Washington County, Pennsylvania. Natural gas production rapidly expanded in Pennsylvania from 195 wells drilled in 2008 to 1,386 in 2010 (Brasier et al. 2011). Based on estimates from the U.S. Energy Information Administration (EIA), the Marcellus Shale has 141 trillion cubic feet of recoverable natural gas and contains nearly 30% of all reserves in the U.S. (EIA 2012). The abundance of natural gas in the U.S. most likely will provide cheap energy for Americans to drive growth in many sectors.

Over the next twenty years, many studies forecast shale gas development to create millions of jobs, billions in tax revenues, and billions in GDP across the U.S. Between 2012 and 2035, the U.S. will spend over $3.0 trillion in capital expenditures for unconventional natural gas activity (IHS 2012). Employment in the shale gas industry is expected to grow 3.76% annually and support over 2.1 million jobs by 2035 (IHS 2012). Tax revenues are expected to grow 3.06% annually and contribute approximately $60 billion to federal, state, and local governments by 2035 (IHS 2012). In 2012, the shale gas industry added $121.7 billion to U.S. GDP; in 2035, it is expected to add $287.1 billion (IHS 2012). Thus, shale gas development may provide significant economic benefits such as job creation and tax revenue generation. However, this industry only represents less than one percent of the U.S. economy.

Shale gas development has sparked a debate over its potential human health and environmental risks. The supporters of natural gas development tend to believe that it will lead to the energy independence of the U.S., significantly reduce greenhouse gas emissions relative to fossil fuel sources, and stimulate local economies. On the other side, the opponents tend to believe that it will increase the risk groundwater contamination, deplete local aquifers, emit more methane into the atmosphere, and damage local infrastructures and landscapes. Proponents of shale gas development mention its major economic benefits, but there is a debate in the literature about the significance of its economic impact. In 2008, New York placed a statewide moratorium on fracking because it wanted to properly evaluate its environmental costs before commercial production. Over 150 local towns in New York have outright banned fracking because of the major uncertainty in community perceptions surrounding its long-term consequences. Looser fracking regulations have allowed shale gas development in states such as Pennsylvania, West Virginia, North Dakota, and Texas.

Literature Review

Industry-funded studies suggest that shale gas development has major economic impacts at the state level. In 2009, Pennsylvania spent $4.5 billion in shale gas development (Considine, Watson, and Blumsack 2010). The economic benefits of this development for Pennsylvania were the creation of more than 44,000 jobs, $389 million in state and local tax revenues, and $3.9 billion in GDP (Considine, Watson, and Blumsack 2010). By 2015, the number of natural gas wells drilled is predicted to nearly quadruple from 710 wells in 2009 to 2,903 wells (Considine, Watson, and Blumsack 2010). This rapid increase in shale gas production corresponds to the Pennsylvania economy potentially creating over 160,000 jobs, $1.4 billion in state and local tax revenues, and $14.5 billion in value added in 2015 (Considine, Watson, and Blumsack 2010).

Similar to Pennsylvania, the state of West Virginia experienced job creation, increased tax revenues, and higher GDP levels. In 2009, the Marcellus Shale development in West Virginia created over 24,000 jobs, $110 million in state and local tax revenues, and $3.1 billion in total value added (Higginbotham et al. 2010). Additionally, this development generated higher levels of income for the state by paying more than $550 million in wages (Higginbotham et al. 2010). In Arkansas, shale gas development in the Fayetteville Shale created 9,500 jobs in 2007 (Center for Business and Economic Research, 2008). The rapid production in shale gas has significantly increased economic activity in other sectors. According to the IO model, the shale gas industry has stimulated the economy through the increased spending patterns of households and between industries and direct payments to landowners. However, industry-sponsored studies tend to overestimate the economic impact of shale gas development relative to academic studies that use the same IO method (Kinnaman 2011). The incentive of the industry-sponsored studies to produce results that have higher economic impact levels may be responsible for this positive bias.

Academic studies tend to estimate smaller economic impacts of shale gas development. In Colorado, Texas, and Wyoming counties, an additional million dollars in natural gas production generated 2.35 more jobs and increased the pre-boom employment level by 1.5% (Weber 2012). Based on these results, natural gas development in the Fayetteville Shale created less than 1,400 jobs in 2007 for Arkansas compared to the industry-funded estimate of 9,500 jobs (Weber 2012). Additionally, Weber (2012) concluded that natural gas development in the Marcellus Shale created around 2,200 jobs in 2009 for Pennsylvania compared to the industry-funded study of Considine, Watson, and Blumsack (2010) that estimated over 44,000 jobs. According to the United States Bureau of Labor Statistics (BLS), employment in the oil and natural gas industry increased by 15,114 at 29.15% annually between 2007 and 2012 for Pennsylvania (Cruz, Smith, and Stanley 2014). Therefore, the BLS found that natural gas development created, on average, roughly 3,020 jobs annually for Pennsylvania. This estimate supports the lower economic impact estimate of Weber (2012).

Most industry-funded studies use the input-output (IO) model to estimate the economic impact of shale gas development. The IO model estimates the direct, indirect, induced, and total economic impacts of shale gas development. The direct impact measures the economic effect of the expenditures by the shale gas industry; the indirect impact measures the economic activities that result from the initial stimulus from the expenditures as the capital flows to other sectors of the economy; the induced impact measures the spending of households that directly or indirectly receive benefits from natural gas development as their income increases; the total impact equals the sum of the direct, indirect, and induced impacts. The IO model provides an image of the economic structure at a certain point in time by accounting for the flow of funds between industries, households, and governments (Stimson, Stough, and Roberts 2006). It has the ability to measure gross output, value added (GDP), tax revenues, employment, and wages and salaries in order to estimate the economic impacts (Considine, Watson, and Blumsack 2010).

Based on historical relationships within the local economy or within similar economies, the IO model uses regional economic multipliers to estimate the cascading effect of how spending in one industry affects other industries of the economy by following the flow of capital between them (PwC 2013). Thus, the regional economic multipliers are coefficients that link each industry in a region to all other industries (Barth 2013). The IO model can estimate the economic impacts from historical observations and forecast the economic impacts on a regional economy (Stimson, Stough, and Roberts 2006).

Despite the benefits of the input-output model, it has major unrealistic assumptions. All individuals have identical spending patterns in the IO model; however, this assumption ignores the potential for transient workers (Wooldridge 2012). The regions with an already established natural gas industry may be able to only hire local workers, but regions with a limited number of skilled workers have to hire outside workers. Transient workers that only temporarily live in the community tend to have different spending patterns than local workers because they spend their incomes on goods and services outside of the local economy. The assumption of identical spending patterns may overestimate the economic impact of natural gas development in a region if a significant portion of its labor force contains temporary workers.

The static time property of the IO model presents more issues for accurate estimations. The regional economic multipliers and prices are held constant over time. This unrealistic assumption doesn't capture the dynamic effects of the natural gas industry on the regional economy (Black, McKinnish, and Sanders 2005). In areas that do not have a developed natural gas industry, there is no way of determining its specific regional economic multipliers based off of historical relationships if it never existed. The IO model uses regional economic multipliers from other regions that have actually experienced natural gas development, but this may not be an accurate representation of the relationships between the industries (Stimson, Stough, and Roberts 2006). Thus, this problem may result in inaccurate conclusions about the economic impacts.

The IO model assumes that a large percentage of the direct industry spending occurs within the regional economy (Kinnaman 2011). On average, most studies used 95% for direct industry spending, but the value may not be an accurate representation of the regional economy (Kinnaman 2011). Additionally, the IO model ignores the possibility of direct spending crowding out other sectors of the economy that use the same resources. Therefore, the assumed large value of direct spending and no crowding out effect may overestimate the local economic impacts of shale gas development. Lastly, the IO model ignores the environmental impacts and negative externalities in its estimation of the economic impacts. The environmental costs of fracking may have significant negative effects on regional economies and reduce the overall economic impacts of shale gas development. Therefore, industry-funded studies may have the incentive to overestimate economic impacts and produce misleading expectations for shale gas development.

In the academic literature, the difference-in-differences (DID) method is used to estimate the economic impact of shale gas development. It estimates the difference between the treatment and control groups both before and after the exogenous event. Muehlenbachs, Spiller, and Timmins (2012) applied the difference-in-difference-in-differences (DDD) method, a variation of the DID method, to a natural experiment including data on property values and proximity to natural gas wells. The "treatment" effect was exposure to groundwater contamination risk. The first treatment group was the property values within 2000 meters from a natural gas well and the first control group was the property values outside of 2000 meters from a well. The second treatment group was the homes that relied on groundwater and the second control group was the homes that relied on the Public Water Service Areas. Since these two treatment and two control groups overlapped for some observations, the DDD model could determine the impact of groundwater contamination risk from shale gas development on property values that rely on groundwater for their water source.

The hedonic price models and triple difference (DDD) estimators have produced mixed results for the impact of shale gas development on local housing prices and the value of the environmental costs of fracking. According to many studies natural gas development has a small negative impact on property values studies. Boxall, Chan, and McMillan (2005) estimated the impact of oil and natural gas development on residential property values in rural areas in Calgary, Canada. They concluded that property values have a statistically significant negative relationship with the number of natural gas wells within four kilometers of the property. Thus, natural gas development significantly reduces housing prices. However, Muehlenbachs, Spiller, and Timmins (2012) investigated this relationship and concluded that there was not a statistically significant relationship between natural gas development and housing prices. The proximity or distance to natural gas wells significantly increased housing values, but the value of groundwater risk completely offsets these economic gains. Additionally, they found that groundwater risk factor reduced property values up to 24%. Taylor, Phaneuf, and Liu (2012) determined that commercial properties reduced neighboring residential property values by 4.5% to 5.5% and environmental contamination reduced them an additional 2.5-3.0%.

Due to the boom-bust cycle of coal mining in the 1970s and 1980s, residents in regions that experienced coal development tended to have negative attitudes towards natural gas development. The residents believed that natural gas industry would rapidly grow and decline similar to the coal industry (Brasier et al. 2011). Ladd (2013) issued a survey to local residents in the Haynesville Shale of Louisiana to understand their perception of the benefits and costs associated with unconventional natural gas production. According to the results, 57% of the respondents believed that the benefits outweighed the costs; however, a significant minority of 31% believed that the costs outweighed the benefits. The most popular environmental costs mentioned were increased road damage, noise, traffic accidents, and the contamination of water resources.

Over the past decade, shale gas development appears to have both positive and negative impacts on local economies. Studies that used the input-output model may not fully capture the social impact due to its unrealistic assumptions and not including environmental costs. IO models resulted in large and positive impacts to both state and local communities, but this may overstate the net benefits of shale gas development. The socioeconomic benefits of shale gas generally were increased jobs, tax revenue generation, value added, and new economic opportunities for local businesses and landowners. Studies that used the hedonic price model determined that the environmental costs of shale gas development significantly reduced housing prices. The major uncertainty surrounding the new unconventional methods of hydraulic fracturing and horizontal drilling have produced mixed attitudes towards this development across local communities. Studies have estimated the short-run economic impacts of shale gas development, but they have generally failed to measure its long-run economic impacts. More studies need to focus on the long-run effects in order to gain a better understanding of the natural gas industry.

Data and Difference-in-Differences Model

This study uses monthly and quarterly data from the Bureau of Labor Statistics Quarterly Census of Employment and Wages (QCEW) program for the period 2001-2013. The BLS data includes private employment and total wages (in thousands) across all industries and establishment sizes at the county level for New York and Pennsylvania. Additionally, the monthly employment data and the quarterly wages data measure economic activity within the natural resources and mining industry. For this study, the natural resources and mining industry is defined as an aggregate of the two sectors: the agriculture, forestry, fishing and hunting (North American Industry Classification System (NAICS) 11) and the mining, quarrying, and oil and gas extraction (NAICS 21). The agriculture, forestry, fishing and hunting sector contains establishments that grow crops, raise animals, and harvest timber, fish, or animals. The mining, quarrying, and oil and gas extraction sector contains establishments that extract naturally occurring mineral solids (coal and ores), liquid minerals (crude petroleum), and gases (natural gas); and support activities for mining activities. The mining sector serves as a better representation of shale gas activity than the larger natural resources and mining industry; however, most of the data in the mining sector is not disclosable because it does not meet BLS or State agency disclosure standards and the data is annual instead of monthly or quarterly. Thus, the natural resources and mining industry provides a more robust data set with more reported data on a shorter time scale.

This study uses several other sources to estimate shale gas development across the whole economy at the county and zip code levels. The United States Census Bureau County Business Patterns includes annual payroll (in thousands), private employment, and establishment data for the period 2003-2011 at the county level for New York and Pennsylvania. The United States Census Bureau Zip Code Business Patterns includes annual payroll (in thousands), private employment, and establishment data for the period 2004-2011 at the zip code level for New York and Pennsylvania. ArcGIS data provides distances (meters) from the New York and Pennsylvania border to the center of each zip code in New York and Pennsylvania. The combination of zip code level and distance data provides distance bands to measure the economic impact of shale gas development at 50,000 meters (31 miles) and 100,000 meters (62 miles) from the border.

The Bureau of Economic Analysis Local Area Personal Income and Employment contains annual private employment, total earnings (in thousands), and per capita personal income at the county level within the mining industry. The mining industry is defined as the aggregate of the oil and gas extraction, mining, except oil and gas, and support activities for mining sectors. The mining industry without the mining, except oil and gas sector may serve as a better representation of shale gas development, but most of the BEA data is not disclosed at the sector level.

This study uses the difference-in-differences method to estimate the economic impact of shale gas development. The difference-in-differences (DID) method attempts to determine the impact of a treatment at a certain point in time. The DID method can be applied to data from a natural experiment. In a true experiment, the treatment and control groups are randomly and explicitly chosen; however, in a natural experiment, these groups are non-random samples because they are "naturally" determined by an exogenous event. The treatment group is affected by the exogenous event, while the control group is not affected by this event. In order to control for systematic differences between the groups, data is required before and after the event. Therefore, the only systematic difference between these groups is the treatment effect.

Besides the non-randomization problem, the unobserved heterogeneity or unobservable omitted variables problem occurs in DID applications because it may be impossible to observe some relevant explanatory variables. In order to try to fix the non-randomization and unobservable omitted variables problems, the DID estimator compares the outcome change in the treatment group with the outcome change in the control group (Card and Krueger 1994). The DID method has four major groups within its sample: the control group before the event, the control group after the event, the treatment group before the event, and the treatment group after the event (Wooldridge 2012).

Card and Krueger (1994) applied the DID method to a natural experiment in New Jersey and eastern Pennsylvania. They used employment data from the fast food industry in both states to investigate the economic impact of raising the minimum wage. Due to New Jersey raising its minimum wage from $4.25 to $5.05 per hour and Pennsylvania holding its minimum wage fixed at $4.25, New Jersey represented the treatment group and Pennsylvania represented the control group. Based on the treatment effect, the minimum wage hike caused a modest increase in employment for the fast food industry in New Jersey.

Natural Experiment

In this study, the counties along the New York and Pennsylvania border serve as a natural experiment for the economic impact of shale gas development. From a spatial perspective, the New York border counties should have more similar attributes to the Pennsylvania border counties relative to the Pennsylvania counties further away from the border. Only sampling from these counties may limit the systematic differences between the treatment and control groups. The ten border counties of New York are Chautauqua, Cattaraugus, Allegany, Steuben, Chemung, Tioga, Broome, Delaware, Sullivan, and Orange. The nine border counties of Pennsylvania are Erie, Warren, McKean, Potter, Tioga, Bradford, Susquehanna, Wayne, and Pike.

A natural experiment has an exogenous event impact a treatment group and not impact a control group at a certain point in time. In this study, the border counties of Pennsylvania serve as the treatment group because it was affected by shale gas development in 2008. The border counties of New York serve as the control group because its fracking moratorium didn’t allow shale gas development. It has major importance because natural experiments usually don't exist in economics because we can't change a policy in order to estimate its impact.

We used the difference-in-differences (DID) method to estimate the economic impact of shale gas development. It estimates the difference between the treatment and control groups both before and after the exogenous event. In this case, it estimates the changes in economic outcomes between the border counties of New York and Pennsylvania before and after shale gas development in 2008. Thus, the application of the DID method to the natural experiment along the border can measure the economic impact of shale gas development.

In this natural experiment, the DID method assumes that if there was no shale gas development in Pennsylvania, the change in the outcome for the border counties of Pennsylvania would equal the change in the outcome for the border counties of New York. The Pennsylvania border counties serve as the treatment group, while the New York border counties serve as the control group. The beginning of 2008 represents the point in time that separates the changes that occurred before and after shale gas development. Therefore, the DID estimates the economic impact of shale gas development by comparing the changes in outcomes before and after 2008.

To investigate the economic impact of shale gas development, we estimate a difference-in-differences model with additional time controls:

$$Y_{ct} = \beta_0 + \beta_1 PA_c + \delta_0 Post2008_t + \delta_1 (PA_c * Post2008_t) + t + t^2 + \varepsilon_{ct} \quad (1)$$

In this study, various economic data (total wages, industry wages, total employment, industry employment, etc.) represent the dependent variable, Y_{ct}, or the outcome of interest. The explanatory variable, PA_c, is the dummy variable for the treatment group – the border counties of Pennsylvania. We assign a one to the border counties of Pennsylvania and a zero to the border counties of New York (control group). The explanatory variable, $Post2008_t$, is the dummy variable for observations after the beginning of shale gas development in 2008. We assign a one to any month, quarter, or year in 2008 and afterwards; we assign a zero to any month, quarter, or year through 2007. The interaction term, $PA_c*Post2008_t$, is the dummy variable for the observations after 2008 in the border counties of Pennsylvania. Thus, we assign a one to any observation after 2008 for the treatment group; otherwise, we assign a zero. The t and t^2 variables represent linear and non-linear time controls, respectively. We assign a unique number identification for each month, quarter, or year in order to account for irregular trends in time such as the Great Recession from the end of 2007 to the middle of 2009. The error term, ε, accounts for all the variables not included in the DID model that help explain the variation in dependent variable.

The coefficients of this model measure the changes in the average outcome of the dependent variable. Using the BLS wages data as an example, the constant, β_0, measures the average wages for the border counties of New York (control group) before 2008. The parameter, β_1, measures the difference in wages between the treatment and control groups before 2008. The parameter, δ_0, measures the change in wages of the control group from before and after 2008. The parameter, δ_1, measures the average treatment effect of shale gas development. Thus, it measures the effect of shale gas development on wages by differencing the differences in the average wages between the border counties of Pennsylvania and New York before and after 2008.

There are several potential problems with our DID model. Firstly, the DID approach assumes that the outcome in the treatment group (PA) and control group (NY) follow the same linear time trend in the absence of the treatment effect (shale gas development). However, it does not control for the possibility that the treatment or controls groups grew at a faster or slower rate before the treatment effect relative to their trend after the treatment effect. Weber (2012) implemented a more robust triple difference approach (DDD) to estimate the economic effects of a natural gas boom in Colorado, Texas, and Wyoming counties in order to account for this potential issue. Secondly, the unobserved heterogeneity problem may arise in our DID model. Relevant explanatory variables that are unobservable, but are correlated with the included explanatory variables may exist. Thus, the omitted variables will be included in the error term and may lead to biased OLS estimates for the correlated explanatory variables.

To investigate the short-term effects of shale gas development, we estimate a difference-in-differences model with year fixed effects:

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

In this study, all of the dependent variables, Y_{ct}, in the DID model with year fixed effects (Equation 2) are the same as the ones in the DID model with time controls (Equation 1). The dummy variable, PA_c, equals one for the border counties of Pennsylvania and zero for the border counties of New York. The interaction term, $PA2008_{ct}$, multiplies the treatment group dummy variable with the time dummy variable for the year 2008. Thus, if it equals one, it represents all the border counties of Pennsylvania in 2008; otherwise, it represents all other observations. There are interaction terms for every year from the period 2008-2013 and their respective parameters estimate the average treatment effect of shale gas development in every year after 2008. The time dummy variable, 2008_t, equals one if the observation is in the year 2008 and zero if it's not. Every year from 2008-2013 has its own time dummy variable and accounts for year fixed effects. Therefore, the DID model with year fixed effects has the ability to detect any changes in short-term trends during the potential boom phase of shale gas development.

Results and Discussion

Our results suggest that shale gas development has a significant positive effect within the natural resources and mining industry, but it does not have a significant impact across the entire local economy. Before shale gas development in 2008, border counties in New York had $115,199,800 more in total wages and 13,152 more private employees across all industries than border counties in Pennsylvania. These results are statistically significant at the 1% level of significance. Before 2008, there are 64 more employees within the industry in a border county of New York than Pennsylvania; however, there is not a statistically significant difference between them for total wages. Across all industries, there is not a statistically significant change in private employment or total wages for New York border counties from before and after 2008. Within the industry, employment decreases by 112 over time and total wages decrease by $2,130,407 for an average New York border county. These results are statistically significant at the 1% level of significance. Shale gas development caused total wages within the natural resources and mining industry to increase by $2,780,348 and private employment to increase by 135 workers for an average border county in Pennsylvania. Both of these results are statistically significant at the 1% level of significance.

Table 1. Employment and Wages DID Results

Variable	Total Wages (1)	Industry Wages (2)	Total Employees (3)	Industry Employees (4)
PA	-115199.8**	-170.7282	-13151.5**	-63.64996**
	(20695.4)	(173.6063)	(1522.831)	(11.65085)
Post2008	1395.971	-2130.407**	-819.827	-111.7327**
	(37872.97)	(599.0841)	(2507.787)	(24.55424)
Interaction	-16258.84	2780.348**	225.7273	134.6039**
	(33895.03)	(610.1623)	(2278.241)	(23.11949)
Observations	950	945	2850	2835

Notes: Robust standard errors are reported within parentheses.
** Indicates two-tailed significance at the 1% level. * Indicates two-tailed significance at the 5% level.

Table 2 represents the results from the DID model with year fixed effects. Before 2008, border counties in New York had $115,199,800 more in total wages and 13,152 more private employees across all industries than border counties in Pennsylvania. These results are statistically significant at the 1% level of significance. Before 2008, there are 64 more employees within the industry in a border county of New York than Pennsylvania and this result is statistically significant at the 1% level. Shale gas development never causes a statistically significant change in total wages or employment across the entire local economy from 2008-2013. After a two-year period from 2008-2009, shale gas development causes a statistically significant change in total wages and employment within the natural resources and mining industry. In 2010, the results are statistically significant at the 5% level and, from 2011-2013, the results are statistically significant at the 1% level. Industry wages increase annually from $2,129,659 in 2010 to $6,300,940 in 2012 before it decreases to $5,828,200 in 2013. Industry employment follows a similar pattern as it increases from 93 in 2010 to 299 in 2012 before it decreases to 243 in 2013.

Table 2. Employment and Wages DID Results with Year Fixed Effects

Variable	Total Wages (1)	Industry Wages (2)	Total Employees (3)	Industry Employees (4)
PA	-115199.8**	-179.6169	-13151.5**	-64.10624**
	(20823.02)	(180.4128)	(1524.979)	(11.76697)
PA2008	-24448.52	-500.7359	-620.5978	6.586794
	(66210.57)	(835.8786)	(4354.818)	(40.27414)
PA2009	-20198.5	-20.88037	-182.9561	-4.059503
	(63556.74)	(682.9797)	(4183.071)	(37.12082)
PA2010	-20643.28	2129.659*	204.1458	93.32476*
	(64496.71)	(1004.447)	(4181.958)	(42.5925)
PA2011	-10570.98	4706.031**	698.3671	234.5789**
	(68095.9)	(1533.103)	(4269.429)	(54.08872)
PA2012	-7989.818	6300.94**	813.5847	299.4861**
	(69315.82)	(2087.668)	(4307.844)	(60.13164)
PA2013	-11145.09	5828.2*	657.9134	243.3377**
	(94385.87)	(2291.018)	(5847.703)	(68.89575)
Observations	950	945	2850	2835

Notes: Robust standard errors are reported within parentheses.
** Indicates two-tailed significance at the 1% level. * Indicates two-tailed significance at the 5% level.

Table 3 represents the DID results based on the US Census Bureau County Business Patterns data. Before 2008, an average border county in New York had $477,287,300 more in annual payroll, 13,806 more private employees, and 1,056 more establishments across all industries than Pennsylvania. These results are statistically significant at the 5% level of significance. From before and after 2008, there is not a statistically significant change in any of these three economic measures for New York border counties. Shale gas development does not cause a statistically significant change in annual payroll, employment, or the number of establishments across the entire economy.

Table 3. Annual Payroll, Employment, and Establishment DID Results

Variable	Annual Payroll (1)	Employees (2)	Establishments (3)
PA	-477287.3*	-13806.93*	-1056.431*
	(205058.2)	(6645.777)	(435.0364)
Post2008	22771.08	-266.4982	2.086579
	(368432.1)	(10917.62)	(801.8728)
Interaction	-65260.88	76.56278	-27.99389
	(323582.6)	(9843.802)	(652.9959)
Observations	171	171	171

Notes: Robust standard errors are reported within parentheses.
** Indicates two-tailed significance at the 1% level. * Indicates two-tailed significance at the 5% level.

Table 4 represents the results from the DID model with year fixed effects for the same data as Table 3. Similar to the results of the original DID model, before 2008, an average border county in New York had $477,287,300 more in annual payroll, 13,806 more private employees, and 1,056 more establishments across all industries than Pennsylvania. For each year between 2008 and 2011, shale gas development does not cause a change in annual payroll, employment, or the number of establishments across the whole economy at the 10% level of significance.

Table 4. Annual Payroll, Employees, and Establishment DID Results with Year Fixed Effects

	Annual Payroll (1)	Employees (2)	Establishments (3)
PA	-477287.3*	-13806.93*	-1056.431*
	(207863.8)	(6727.83)	(440.4129)
PA2008	-90294.31	-643.2844	-38.51333
	(551632)	(16583.67)	(1096.494)
PA2009	-70821.1	61.67	-21.84667
	(533571)	(15985.51)	(1087.753)
PA2010	-64873.51	181.1378	-39.25778
	(543273.2)	(15886.84)	(1071.8)
PA2011	-35054.62	706.6378	-12.35778
	(561728.3)	(16204.99)	(1063.083)
Observations	171	171	171

Notes: Robust standard errors are reported within parentheses.
** Indicates two-tailed significance at the 1% level. * Indicates two-tailed significance at the 5% level.

Table 5 represents the DID results with distance bands from the New York and Pennsylvania border based on the US Census Bureau Zip Code Business Patterns data. Before 2008, an average zip code area in New York had $91,174,460 more in annual payroll, 1,079 more private employees, and 98 more establishments across all industries than Pennsylvania. These results are statistically significant at the 1% level of significance. None of these economic measures are statistically significant within 50,000 meters of the border; however, they are statistically significant within 100,000 meters of the border at the 1% level. From before and after 2008, there is not a statistically significant change in any of these three economic measures for New York zip codes regardless of the distance from the border. Shale gas development does not cause a statistically significant change in annual payroll, employment, or the number of establishments at the zip code level.

Table 5. Zip Code Level DID Results with Distance Bands

Variable	Annual Payroll (1)	Annual Payroll ≤ 50,000 m (2)	Annual Payroll ≤ 100,000 m (3)	Employees (4)	Employees ≤ 50,000 m (5)	Employees ≤ 100,000 m (6)
PA	-91174.46**	-5798.851	-257829.8**	-1079.806**	-70.02715	-3543.802**
	(11363.19)	(4710.28)	(25823.81)	(146.4014)	(159.7222)	(294.6934)
Post2008	5679.355	966.0244	11538.8	159.1949	47.39314	215.4154
	(24690.88)	(9236.777)	(66007.3)	(278.7711)	(299.374)	(663.5999)
Interaction	-15054.64	-2617.031	-46488.31	-146.1701	-75.97979	-421.3816
	(17380.72)	(7200.386)	(39216.59)	(215.3625)	(235.0263)	(430.4967)
Observations	27853	3242	8828	26881	3094	8536

Notes: Robust standard errors are reported within parentheses.
** Indicates two-tailed significance at the 1% level. * Indicates two-tailed significance at the 5% level.

Table 5 (Continued).

Variable	Establishments (7)	Establishments ≤ 50,000 m (8)	Establishments ≤ 100,000 m (9)
PA	-98.23268**	-4.578683	-236.9105**
	(6.775513)	(7.978378)	(14.85893)
Post2008	1.734556	0.4774829	1.163594
	(12.1463)	(13.72821)	(30.82357)
Interaction	-4.894528	-2.3662	-8.461279
	(9.572205)	(11.23741)	(20.85573)
Observations	33267	3576	9553

Notes: Robust standard errors are reported within parentheses.
** Indicates two-tailed significance at the 1% level. * Indicates two-tailed significance at the 5% level.

Table 6 represents the results from the DID model with year fixed effects for the same data as Table 5. Similar to the original DID model, before 2008, an average zip code area in New York had $91,226,320 more in annual payroll, 1,080 more private employees, and 98 more establishments across all industries than Pennsylvania. These results are statistically significant at the 1% level of significance. Additionally, none of these economic measures are statistically significant within 50,000 meters of the border; however, they are statistically significant within 100,000 meters of the border at the 1% level. Shale gas development does not cause as statistically significant change in annual payroll, employment, or the number of establishments each year from 2008-2011 at the zip code level regardless of the distance from New York and Pennsylvania border.

Table 6. Zip Code Level DID Results with Distance Bands and Year Fixed Effects

Variable	Total Annual Payroll (1)	Annual Payroll ≤ 50,000 m (2)	Annual Payroll ≤ 100,000 m (3)	Employees (4)	Employees ≤ 50,000 m (5)	Employees ≤ 100,000 m (6)
PA	-91226.32**	-5768.397	-257783.8**	-1080.053**	-69.54912	-3544.299**
	(11370.11)	(4713.463)	(25823.5)	(146.4309)	(159.8641)	(294.8074)
PA2008	-21622.62	-2298.129	-62408.06	-162.6648	-18.95187	-420.4274
	(30556.4)	(11970.49)	(69615.11)	(357.5161)	(391.3576)	(714.3706)
PA2009	-5195.833	-3920.186	-23821.11	-141.8837	-87.00543	-402.812
	(26654.48)	(11537.37)	(59332.42)	(346.564)	(376.4683)	(688.7077)
PA2010	-15941	-3860.523	-45475.05	-142.4217	-136.2835	-393.347
	(27934.67)	(11858.61)	(62874.82)	(339.6767)	(375.6072)	(678.0286)
PA2011	-17251.46	-490.3891	-54576	-136.0951	-61.15811	-463.8821
	(29329.87)	(12125.28)	(65565.28)	(348.6948)	(377.6478)	(692.4271)
Observations	27853	3242	8828	26881	3094	8536

Notes: Robust standard errors are reported within parentheses.
** Indicates two-tailed significance at the 1% level. * Indicates two-tailed significance at the 5% level.

Table 6 (Continued).

Variable	Establishments (7)	Establishments ≤ 50,000 m (8)	Establishments ≤ 100,000 m (9)
PA	-98.23387**	-4.578326	-236.9102**
	(6.775939)	(7.98278)	(14.86206)
PA2008	-2.586634	-1.856638	-4.269804
	(15.17774)	(17.89216)	(32.98091)
PA2009	-3.055653	-2.246568	-5.590287
	(15.06341)	(17.78593)	(32.7127)
PA2010	-6.43892	-3.150629	-10.4221
	(15.10476)	(17.65095)	(32.76422)
PA2011	-7.500091	-2.212393	-13.54305
	(15.16009)	(17.60661)	(32.86817)
Observations	33267	3567	9533

Notes: Robust standard errors are reported within parentheses.
** Indicates two-tailed significance at the 1% level. * Indicates two-tailed significance at the 5% level.

Table 7 represents the DID results for the Bureau of Economic Analysis Personal Income and Employment data. Before shale gas development in 2008, the average total earnings in the mining industry of a Pennsylvania border county is $5,272,901 higher than a New York; however, there are 19,175 less employees in a Pennsylvania border county. These results are statistically significant at the 1% level of significance. There is not a statistically significant difference for per capita personal income in the mining industry. From before and after 2008, there is not a statistically significance change in average earnings, employment, or per capita personal income within the mining industry in the New York border counties. Shale gas development increased total earnings by $16,236,160 within the mining industry, but it decreased per capita personal income by $1,589 for an average Pennsylvania border county. These results are statistically significant at the 5% level. Shale gas development did not cause a statistically significant change in mining industry employment.

Table 7. Employment, Earnings, and Per Capita Personal Income DID Results

Variable	Mining Employment (1)	Mining Earnings (2)	Mining Per Capita Personal Income (3)
PA	-19175.37**	5272.901**	-710.3048
	(6301.911)	(1938.581)	(403.8599)
Post2008	-163.1148	-13773.02	1153.358
	(12493.24)	(7173.728)	(1019.058)
Interaction	-25.39603	16236.16*	-1588.762*
	(10390.43)	(6836.523)	(732.4089)
Observations	209	180	209

Notes: Robust standard errors are reported within parentheses.
** Indicates two-tailed significance at the 1% level. * Indicates two-tailed significance at the 5% level.

Table 8 represents the DID results with year fixed effects of the same data as Table 7. Similar to the original DID model, before 2008, the average total earnings in the mining industry of a Pennsylvania border county is $5,208,202 higher than a New York; however, there are 19,175 less employees in a Pennsylvania border county. The earnings and employment results are statistically significant at the 5% and 1% level of significance, respectively. There is not a statistically significant difference for per capita personal income in the mining industry. Shale gas development does not cause a statistically significant change in employment, earnings, or per capita persona income for each year from 2008-2011.

Table 8. Employment, Earnings, and Personal Income DID Results with Year Fixed Effects

Variable	Mining Employment (1)	Mining Earnings (2)	Mining Per Capita Personal Income (3)
PA	-19175.37**	5208.202*	-710.3048
	(6364.861)	(2039.11)	(536.2754)
PA2008	-774.346	7086.671	-1506.94
	(18237.04)	(9806.549)	(1356.024)
PA2009	-344.8571	3634.898	-1708.584
	(17649.33)	(8003.136)	(1302.757)
PA2010	156.854	19296.85	-1892.684
	(17653.12)	(12411.69)	(1287.929)
PA2011	860.7651	34208.55	-1246.84
	(17887.77)	(18516.27)	(1301.397)
Observations	209	180	209

Notes: Robust standard errors are reported within parentheses.
** Indicates two-tailed significance at the 1% level. * Indicates two-tailed significance at the 5% level.

Natural Resource Curse

Local economies that produce shale gas and rapidly grow may experience the "natural resource curse." According to this theory, economies that depend more on natural resources have slower long-term economic growth (Frankel 2010). There is a low negative correlation between natural resource economies and economic growth; however, there are a mix of successes and failures (Frankel 2010). During the 1970s and 1980s, the coal boom and bust affected local economies in Kentucky, Ohio, Pennsylvania, and West Virginia. Black, McKinnish, and Sanders (2005) found that the coal boom increased employment two percentage points higher, earnings five percentage points higher, and significantly reduced poverty in coal counties than in non-coal counties. The boom phase lasted for over a decade until the bust phase eliminated its economic benefits.

The boom and bust cycle of the coal industry can serve as a case study for the natural gas industry. Local economies that are more dependent on natural gas are more likely to have greater growth in employment and income than more diversified economies. However, the more dependent economies are more likely to have slower economic growth in the long run. In Pennsylvania, rapid production in shale gas has attracted more workers as industry wages are increased. The shale gas boom may continue over the short run, but the shale gas bust is inevitable because it's a non-renewable natural resource. Once shale gas production slows down, employment levels will decline and industry workers may be forced to find new jobs.

Our results suggest that shale gas development did not significantly increase employment and wages within the natural resources and mining industry until two years after the beginning of rapid production in Pennsylvania. After this two-year lag, Pennsylvania experienced a shale gas boom as employment levels grew 37.6% annually and wages grew 39.9% annually from 2010 to 2013. Thus, local economies may not immediately experience the benefits of the shale gas boom, but will experience major growth in this industry in the years following the delay. Despite major industry growth, shale gas development never caused economic growth across all industries in Pennsylvania because of its insignificant size relative to the overall local economy.

Conclusions

The popular methods used in the recent primary literature do not fully capture the social impact of shale gas development. Due to its unrealistic assumptions, the input-output (IO) model tends to overestimate its net economic benefits. Additionally, the IO model ignores the environmental costs of fracking on local communities. The hedonic price model has the ability to estimate the environment costs, but it fails to capture most of the potential economic benefits. The difference-in-differences (DID) model may be able to more accurately estimate the economic impact of shale gas development over time than the IO model. However, unobserved heterogeneity may cause significant problems with the precision of the results. In this study, the DID model did not account for the economic impact of the recession and omitted a potentially relevant variable that measures the attitudes of communities in Pennsylvania and New York.

Shale gas development has a significant economic impact at the industry level, but not across the whole economy. Policymakers should lower their expectations of shale gas booms from industry-funded results because of unrealistic assumptions that lead to overestimations. A shale gas boom will create jobs, increase wages, and generate tax revenues for local and state governments; however, a shale gas bust may eliminate all of its economic benefits. Due to the recent technological advancements in the natural gas industry of horizontal drilling and hydraulic fracturing, many local economies are experiencing the boom phase and are uncertain about the bust phase. Based on the boom-bust cycle of the coal industry, policymakers should understand that economic growth due to shale gas development is a short-term phenomenon and prepare their communities for the bust in the long-term. Looking beyond this study, if policymakers impose excise taxes on the industry and diversify their communities early enough, the communities may successfully take advantage of the economic benefits of shale gas development.

Policy Implications

The natural gas industry does not represent a large enough part of the economy for shale gas development to significantly improve local economies. It will improve employment and wages within the industry, but its economic impact may not be as large as industry-funded studies suggest. Before shale gas development in the Marcellus Shale, the natural resources and mining industry only accounted for 2% of the total employment and wages in the Pennsylvania counties along the New York border. After shale gas development, this industry accounted for 4% of the total employment and wages in the Pennsylvania border counties. Additionally, local and state governments need to evaluate the local infrastructure relative to other natural gas economies across the U.S. In North Dakota, the rapid production in the Bakken Shale led to faster economic growth than areas with more complex infrastructure such as the Barnett Shale in Texas. Therefore, policymakers need to adjust their expectations for its economic impact based on the size of the natural gas industry relative to the entire local economy and the local infrastructure.

Local and state governments need to take advantage of the shale gas booms and prepare for shale gas busts. They should implement an excise tax on the natural gas industry that internalizes the external costs of shale gas production. The optimal excise tax should be set equal to the marginal social cost of shale gas extraction in order to reduce production levels to the socially optimal quantity (Kinnaman 2011). In order to determine the amount to tax, governments need to perform a cost-benefit analysis of shale gas development in the local economy. This process should account for both the potential economic and environmental risks over the short and long-term. The excise tax may slightly reduce shale gas production and revenue generation for governments, but it should increase the overall benefits to communities.

Natural resource busts tend to have a greater negative impact on economies dependent on natural resources than more diversified economies. Local and state governments should diversify local economies sooner rather than later in order to limit the negative consequences of the bust phase. After the implementation of excise taxes for natural gas companies, they can reduce taxes for local businesses in order to attract greater economic activity in other industries.

Additionally, they can invest the short-term gains from the shale gas boom in other industries to improve the long-term growth for communities.

It is the responsibility of the government to inform their communities about the economic and environmental implications of shale gas development. Every community has its own perception of the benefits and risks associated with shale gas. The government and natural gas companies need to communicate the boom and bust cycle of natural resources, its economic and environmental risks, and its short-term and long-term costs and benefits. A better-informed community has a greater chance of adapting its economy to shale gas development and maximizing its potential benefits.

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, Dan, Terra McKinnish, and Seth Sanders. 2005. "The Economic Impact Of The Coal Boom And Bust*." *The Economic Journal* 115(503): 449-476.

Blohm, Andrew, Jeremy Peichel, Caroline Smith, and Alexandra Kougentakis. 2012. "The Significance of Regulation and Land Use Patterns on Natural Gas Resource Estimates in the Marcellus Shale." *Energy Policy* 50: 358-369.

Boxall, Peter C., Wing H. Chan, and Melville 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, Kathryn J., Matthew R. Filteau, Diane K. McLaughlin, Jeffrey Jacquet, Richard C. Stedman, Timothy W. Kelsey, and Stephan 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.

Card, David, and Alan B. Krueger. 1994. “Minimum Wages and Employment: A Case Study of the Fast Food Industry in New Jersey and Pennsylvania.” *American Economic Review* 84(4): 772-793.

Center for Business and Economic Research. 2008. “Projecting the Economic Impact of the Fayetteville Shale Play for 2008-2012.” University of Arkansas College of Business, Fayetteville, AK.

Considine, Timothy J., Robert Watson, and Seth Blumsack. 2010. "The Economic Impacts of the Pennsylvania Marcellus Shale Natural Gas Play: An Update." Pennsylvania State University College of Earth and Mineral Sciences, State College, Pennsylvania.

Cruz, Jennifer, Peter W. Smith, and Sara Stanley. 2014. “The Marcellus Shale Gas Boom in Pennsylvania: Employment and Wage Trends.” *Monthly Labor Review*, U.S. Bureau of Labor Statistics, Washington, D.C.

Frankel, Jeffrey A. 2010. “The Natural Resource Curse: A Survey.” Working Paper 15836, National Bureau of Economic Research, Cambridge, MA.

Higginbotham, Amy, Adam Pellillo, Tami Gurley-Calvez, and Tom 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.

IHS. 2012. “America’s New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy.” Washington, DC.

Jacquet, Jeffrey B. 2012. "Landowner Attitudes toward Natural Gas and Wind Farm Development in Northern Pennsylvania." *Energy Policy* 50: 677-688.

Kinnaman, Thomas C. 2011. "The Economic Impact of Shale Gas Extraction: A Review of Existing Studies." *Ecological Economics* 70(7): 1243-1249.

Ladd, Anthony E. 2013. "Stakeholder Perceptions of Socioenvironmental Impacts From Unconventional Natural Gas Development and Hydraulic Fracturing in the Haynesville Shale." *Journal of Rural Social Sciences* 28(2): 56-89.

Muehlenbachs, Lucija, Elisheba Spiller, and Christopher Timmins. 2012 “Shale Gas Development and Property

Values: Differences across drinking water sources." Working Paper 18390, National Bureau of Economic Research, Cambridge, MA.

PricewaterhouseCoopers (PwC) LLP. 2013. "Economic Impact Analysis of the Coal Mining Industry in British Columbia, 2011." Coal Association of Canada, Calgary, Alberta, Canada.

Stimson, Robert John, Roger R. Stough, and Brian H. Roberts. 2006. *Regional Economic Development: Analysis and Planning Strategy* (2nd edition). New York, NY: Springer.

Taylor, Laura O., Daniel J. Phaneuf, and Xiangping Liu. 2012. "Disentangling the Impacts of Environmental Contamination from Locally Undesirable Land Uses." Unpublished manuscript.

United States Energy Information Administration (EIA). 2012. "Annual Energy Outlook 2012." U.S. Department of Energy, Washington, D.C.

_______. 2013. "Annual Energy Outlook 2013." U.S. Department of Energy, Washington, D.C.

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

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