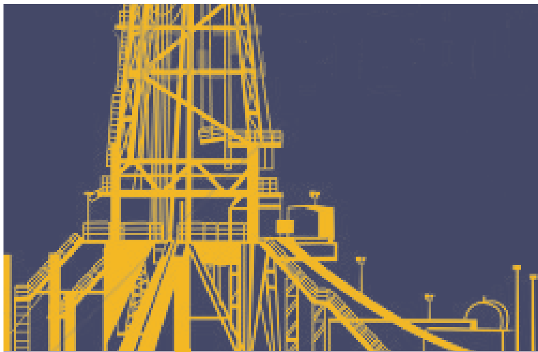

UNIVERSITY OF MICHIGAN

Economics Technical Report

HYDRAULIC FRACTURING IN THE STATE OF MICHIGAN

ABOUT THIS REPORT

This document is one of the seven technical reports completed for the **Hydraulic Fracturing in Michigan Integrated Assessment** conducted by the University of Michigan. During the initial phase of the project, seven faculty-led and student-staffed teams focused on the following topics: **Technology**, **Geology/Hydrogeology**, **Environment/Ecology**, **Human Health**, **Policy/Law**, **Economics**, and **Public Perceptions**. These reports were prepared to provide a solid foundation of information on the topic for decision makers and stakeholders and to help inform the Integrated Assessment, which will focus on the analysis of policy options. The reports were informed by comments from (but do not necessarily reflect the views of) the **Integrated Assessment Steering Committee**, expert peer reviewers, and numerous public comments. Upon completion of the peer review process, final decisions regarding the content of the reports were determined by the faculty authors in consultation with the peer review editor. These reports should not be characterized or cited as final products of the Integrated Assessment.

The reports cover a broad range of topics related to hydraulic fracturing in Michigan. In some cases, the authors determined that a general discussion of oil and gas development is important to provide a framing for a more specific discussion of hydraulic fracturing. The reports address common hydraulic fracturing (HF) as meaning use of hydraulic fracturing methods regardless of well depth, fluid volume, or orientation of the well (whether vertical, directional, or horizontal). HF has been used in thousands of wells throughout Michigan over the past several decades. Most of those wells have been shallower, vertical wells using approximately 50,000 gallons of water; however, some have been deeper and some have been directional or horizontal wells. The reports also address the relatively newer high volume hydraulic fracturing (HVHF) methods typically used in conjunction with directional or horizontal drilling. An HVHF well is defined by the State of Michigan as one that is intended to use a total of more than 100,000 gallons of hydraulic fracturing fluid. The reports indicate if the text is addressing oil and gas development in general, HF, or HVHF.

Finally, material in the technical reports should be understood as providing a thorough hazard identification for hydraulic fracturing, and when appropriate, a prioritization according to likelihood of occurrence. The reports do not provide a scientific risk assessment for aspects of hydraulic fracturing.

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HYDRAULIC FRACTURING IN THE STATE OF MICHIGAN

Economic Dimensions to Hydraulic Fracturing in Michigan with a Focus on Employment

SEPTEMBER 3, 2013

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THIS PUBLICATION IS A RESULT OF WORK SPONSORED BY THE UNIVERSITY OF MICHIGAN
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EXECUTIVE SUMMARY

In Michigan, nearly all natural gas extraction uses hydraulic fracturing. This report discusses four economic topics related to gas extraction: (1) state revenues from royalties, taxes, leases and storage, (2) earnings from private royalties and leases, (3) changes in property values, and (4) employment. Our detailed examination of employment analyzes direct industry, indirect supply chain, and induced forms of employment.

Taxes paid to the State of Michigan from revenues earned by private landowners in 2010 were $32.6 million. These monies support the State general fund. In addition, the State of Michigan earns revenue from gas extracted from State property. In 2012, the Department of Natural Resources (DNR) received $18.4 million in royalties, $7.7 million in bonuses and rent, and a $0.1 million in storage fees. Revenue from FY 2012 was low in comparison to previous periods in the last decade. Nearly all the revenue from gas extracted on State property is used to improve State land and game areas.

Private land owners earn revenue from royalties and leases when gas developers tap mineral resources. We estimate private earnings of $81.5 million in 2010. The magnitude of these payments is tied to gas production volume and natural gas spot prices, which have varied from $9.80 per Mcf (in 2008) to $2.81 per Mcf (in 2012).

Hydraulic fracturing may lead to greater disparity in property values. Landowners that own mineral rights and are positioned to earn revenues from gas extraction are likely to experience a gain in their property values. Land owners in the vicinity of gas wells but who do not hold title to productive mineral rights often experience a decline in property values, depending on proximity to the gas well and well attribute. This topic has yet to be studied in the Michigan context.

Our analysis and most of our discussion centered on the employment effects of gas extraction. We found differences between direct industry jobs involved in production (NAICS 211: Oil and Gas Extraction) and direct industry jobs that provide services to producers (NAICS 213: Support Activities for Mining). In general, production jobs are fewer in number, pay higher salaries, and are less sensitive to well development than servicing jobs. Estimated statewide employment in natural gas production (NAICS 211) ranged from a high of 474 (in 2010) to a low of 394 (in 2002). Statewide employment in service industries ranged from 1,566 (in 2008) to 1,191 (in 2002). Independent contractors add an estimated 4 to 8 percent on top of these figures.

Many of the jobs in gas extraction are technical and offer above-average salaries. We would anticipate that with high-volume hydraulic fracturing the number of technical jobs will increase, while less-skilled laborer positions will decline.

Service firms bear the brunt of industry boom and bust, and are approximately three times the size of direct producing employment. Moreover, the indirect job multiplier for servicing firms is about twice the size of the multiplier for gas producers. This difference suggests that servicing firms are much more likely than producers to purchase inputs from Michigan-based firms.

In terms of job creation, we found a difference between new well drilling and reworked wells. The per well direct and indirect full time equivalent (FTE) employee was substantively greater for reworked wells than for new wells. This disparity might be due to the comparatively heavy use of non-Michigan labor for new well drilling. Induced employment appears to be greater with new wells than reworked wells, which might be capturing the effects of industry growth in a region.

All together, the gas extraction industry creates employment and income for Michigan, but the employment effects are modest compared with other industries, and not large enough to "make or break" the Michigan economy. Our analysis suggests that from an economic development perspective, the State may enjoy stronger job creation by encouraging the rework of existing gas wells rather than by drilling new wells. Further, it might be possible for the State to develop domestic technical capacity for hydraulic fracturing as a method of improving the employment gains that are associated with new well drilling.

1.0 INTRODUCTION

Our objective is to canvass the major economic effects of hydraulic fracturing for natural gas in Michigan. In this preliminary overview, we discuss four economic topics relevant to natural gas extraction: earnings from private royalties and leases, state revenues from royalties, taxes, leases and storage, changes in property values, and employment. For the first three topics we provide a contextual description for Michigan, and develop simulations or present administrative data. The remainder of the report will be dedicated to an original analysis of the effects of natural gas extraction on direct, indirect and induced State employment.

We have two motives for directing attention toward employment. First, jobs are at the center of the political debates over the costs and benefits of industry expansion. Jobs are, normatively, welcomed by a state or region. However, industries like natural gas extraction are controversial because the good, natural gas, is a nonrenewable resource, and the primary extraction method, hydraulic fracturing, potentially imposes negative externalities on proximate communities and on posterity. These industry traits make retroactive restitution problematic and thus, pro-active government regulation necessary. Even with strict precautionary measures, concerns about the potential long-term environmental and health liabilities among the public remain a source of resistance. Industry actors respond with promises of job and income growth to overcome objections to development.[i]

Second, we have acquired the resources to contribute to the extant literature on industry growth and employment. Previous estimates for the industry effect on job growth have not matched industry activity to actual job counts. We have compiled data from the Michigan Department of Environmental Quality (DEQ) on industry activity to match against county-level employment data from the Quarterly Census of Employment and Wages (QCEW). Both data sources provide statistics for the Michigan counties. The QCEW data for less-populated counties is based on an imputation method.

Using these data we estimate the change in direct, indirect, and induced employment as it relates to industry production and well construction. Specifically, our original analysis on employment will address three questions:

1. What are the direct local employment effects of natural gas extraction? This involves establishing estimates for the within industry employment gains with respect to increases in well development and production.

2. What are the indirect employment effects of natural gas extraction? Here, we build from the direct industry estimates to establish projections for the employment change along the industry supply chain.

3. What are the induced employment effects of natural gas extraction? This analysis will estimate the local job changes in other industries associated with jobs in gas extraction.

At the outset, we acknowledge that our analysis on employment cannot distinguish between the effects of "high-volume" and "low-volume" hydraulic fracturing.[ii] This is not to suggest that the difference is inconsequential, but rather, to state that the data at hand are insufficient for isolating the effect of high-volume techniques. The data we analyze covers the previous decade, which is predominately based on low-volume hydraulic fracturing.

To apply our estimates to high-volume hydraulic fracturing one must assume that the industrial processes for high-volume and low-volume hydraulic fracturing have very similar economic effects. This may not strictly be the case. For instance, high-volume hydraulic fracturing will often use directional drilling that demands a skill set and technology than is not needed for low-volume hydraulic fracturing. Moreover, high-volume hydraulic fracturing reduces the surface area "footprint" of the operation, which means fewer well pads for a geographic area. Either of these changes will likely affect employment. We can hypothesize that the efficiencies motivating high-volume processes will increase the demand for technical labor, and simultaneously reduce the number of workers needed for certain phases of production. Higher skilled (and better compensated) but fewer workers is how many industries evolve.

In essence, our review is retrospective and therefore not ideal for predicting how the expansion of high-volume methods will affect employment. Nonetheless, the extent that high-volume and low-volume methods use similar crews, technology, and other non-labor inputs, our results should reasonably estimate the employment changes in Michigan should gas extraction expand. Presently, nearly all of the natural gas extraction in Michigan uses hydraulic fracturing.

2.0 STATUS AND TRENDS

2.1 Industry Activity and Jobs in Michigan

A first step toward understanding the gas extraction industry was to map the activities, job titles, full-time equivalents (FTE), and duration of each production phase. Industry experts informed us that there were five major phases in well development: (l) leasing, (2) exploration, (3) drilling, (4) producing, and (5) site plugging and restoration. Table 1 lists the activities and major occupations involved in each of these phases.

The occupations listed in Table 1 are not exhaustive. The gas extraction industry requires numerous non-specialized occupations, such as accountants, auditors, financial analysts, administrative assistants, truck drivers, and so forth. The MSETC[2] assessment reported over 150 occupations in this industry.

To provide a sense for the compensation range across the core jobs in the gas extraction industry, compensation figures and employment projections for occupations that specialize in natural gas extraction were obtained from the Bureau of Labor Statistics.

i. For an example, see: IHS Global Insight[1].

ii. The Department of Environmental Quality defines high-volume as requiring more than 100,000 gallons of water.

TABLE 1: Production Phases, Activities and Occupations

Phase	Activity	Key Occupations
Leasing	Land procurement for exploration. The purpose is to find and meet mineral rights owners to arrange for lease and royalty contracts.	Landmen (real estate and gas law specialists), attorneys
Exploration	Geophysical tests. For conventional reservoirs that are bounded by hard rock, holes are drilled, charges are fired, and seismic tests are performed to determine the character of the formation. Unconventional reservoirs (resource plays) are drilled without seismic testing. Workers build a drill pad (3-5 acres), drill water well, build holding pond, assess water impact with a water withdrawal assessment tool to test the impact on water tables – 5 to 7 million gallons needed per well.	Geologists, operating engineers, general labor, drivers
Drilling	Erect drilling rig, set up storage, derrick, and mud pumps. If well is dry, it is plugged. Requires 1 to 2 weeks. If the well is productive, then more equipment is deployed for production (separator, storage, compressor, pole barn structure around compressor). A gathering line is built that connects to a transmission line. This phase uses almost all prefabricated equipment. Requires additional 1 to 2 weeks. Total time for a well that produces is about 30 days, but may be as high as 120 days depending on well conditions and knowledge of regulations.	Superintendant or toolpusher, drilling team (driller, derrick man, and floorhand), geologist or mud logger, concrete crew (1 day), engineer, drivers, roustabout
Production	Lease operator or mechanic to check site once per day and perform occasional repair. This phase lasts as long as the well is economically viable, which can be decades and provide long-term employment.	Mechanic (can handle 12 or so wells per day)
Plugging and restoration	Injection of cement, (2-3 days). Site restoration requires an operating engineer. Site must be re-vegetated to prevent erosion.	Crew of 3, cement crew, drivers, operating engineer

Source: Expert interviews from DEQ, industry specialists, and site visit November 28, 2012.

TABLE 2: Occupations in Gas Extraction, Pay, and Projections, as of 2011

Occupation Title (BLS)	Annual Compensation	Projected Growth
Petroleum Engineers	122,280	Average
Mining and Geological Engineers	84,300	Average
Hydrologists	75,680	Average
First-Line Supervisors (extraction)	59,150	Faster than average
Property & Real Estate Managers	52,510	Slower than average
Rotary Drill Operators	51,310	Slower than average
Geological and Petroleum Technicians	49,690	Average
Geophysical Data Technicians	49,690	Average
Mobile Heavy Equipment Mechanics	45,600	Average
Operating Engineers	41,510	Faster than average
Wellhead Pumpers	41,320	Slower than average
Service Unit Operators	40,750	Slower than average
Extraction Workers	40,030	Decline
Roustabouts	32,980	Slower than average
Helpers—Extraction Workers	32,870	Slower than average

Source: Bureau of Labor Statistics, accessed at: www.onetonline.org

As displayed in Table 2, gas extraction is a relatively high-wage industry. About half of the occupations listed in Table 2 are near or above the median household income for Michigan ($48,669 average 2007–2011).[iii]

The occupations in Table 2 are involved in well development; however the natural gas supply system does not end with well drilling and production. Gas that is extracted must be processed, compressed, transported, and stored. When a new well is drilled, producers are responsible for laying a gathering line from the well to the nearest transmission line. Compressor stations, located in proximity to a cluster of wells removes impurities, separates gas into component parts and compresses the gas for transmission to buyers. An interstate system of transmission lines (primarily underground) transports gas to utilities and end users. Firms that own the transmission lines earn a fee to transport product.

Once the natural gas arrives to utility companies or commercial end users it is often stored underground for later use to contend with seasonal or cyclical demand. Energy distribution companies, for instance, store gas during the summer in order to have stock available for the peak winter season. Storage rights are a surface right, and the state or private landowners that lease gas storage space receive payments from gas production and distribution companies.

The transmission and storage system is necessary because the location of the natural resource is primarily in the northern half of the lower Michigan peninsula, whereas the population centers (and hence, end users) are in southern Michigan. Economic activity for gas extraction therefore occurs in rural northern regions. To visualize this, we prepared two maps of Michigan counties that partially capture regional economic activity. Figure 1 presents a "heat" score based on the location of active gas wells in 2012.

Note a high density of wells in the northern region of the lower peninsula, and that the most active counties are at the center of the land mass, as opposed to near lakes.

Figure 2 presents QCEW job counts in two NAICS three-digit categories: Oil and Gas Extraction[iv] (211) and Support Activities for Mining[v] (213) based on the average for Michigan counties over the 2001 to 2011 period.

Figure 1: Heat Map of Active Wells in Michigan by County

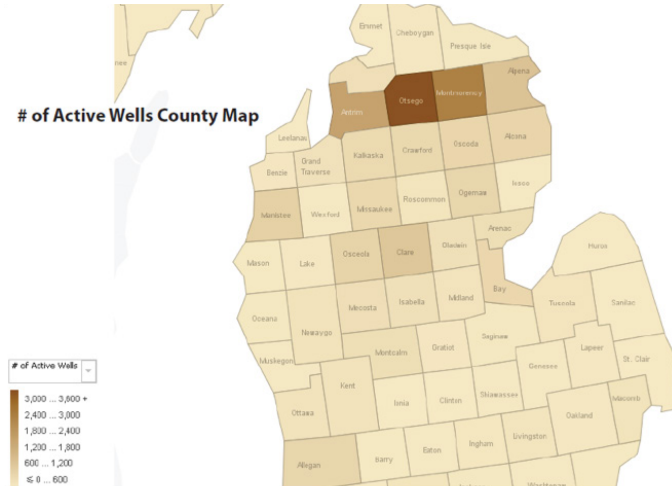
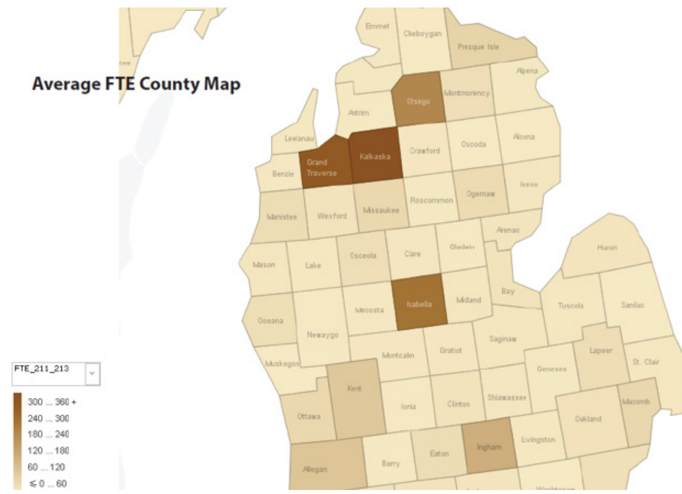


Figure 2: Heat Map Gas Extraction Employment in Michigan by County



Observe by comparing the maps that the well locations are not necessarily where industry jobs are located. The wells are of course constrained to be above resource plays, which tend to be at the center of the lower Michigan peninsula land mass. Jobs, however, are located closer to urban areas of Traverse City, or towns such as Kalkaska and Mount Pleasant. Firms locate near well production, but in places that are desirable enough to attract and retain talent. The implication for our analysis is that there are two spatial dimensions of economic activity, i.e. the well location and the employment location.

The spatial disconnect between well and firm location is inherent with the approximately 20 percent of the firms with wells in Michigan that have out-of-state corporate addresses. Figure 3 below provides the breakdown of in-state and out-of-state firms with Michigan gas wells. About 7 percent of the total firms are from Texas, and 14 percent are from all other states and Canada.

iii. Source: U.S. Census Bureau, accessed at: http://quickfacts.census.gov/qfd/states/26000.html. Household income includes multiple earners. The jobs listed in Table 2 are therefore sufficient for meeting the state average with only one earner.

iv. Oil producing wells are approximately 20 percent of wells in Michigan, with most located in southern Michigan.

v. Support activities include well drilling and gas operation.

Figure 3: Origin of Gas Companies Operating in Michigan

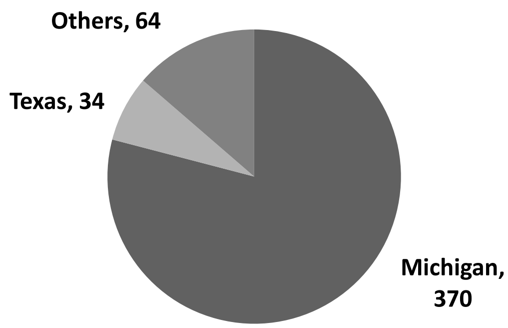


Figure 4: Gas Price[vi] and Gas Production by Michigan & Non-Michigan Companies

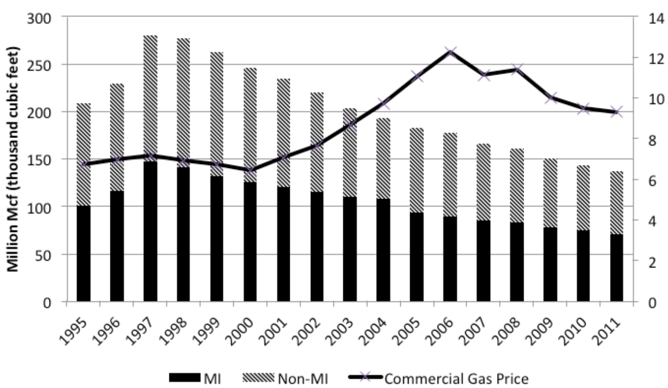
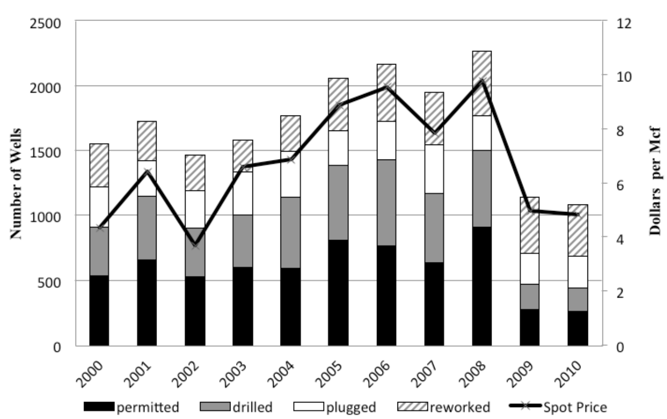


Figure 5: Gas Price[4] and Gas Production by Michigan & Non-Michigan Companies



In-state firms are more numerous, but on average smaller as measured by annual production. This is evident from Figure 4, which provides the annual production volumes by in-state and out-of-state firms.

vi. Source: U.S. Energy Information Administration, U.S. Department of Energy, accessed at: http://www.eia.gov/dnav/ng/hist/n3020mi3m.htm

Observe from Figure 4 that out-of-state firms, although fewer in number, have in the past decade accounted for just under half of the gas production in Michigan. Figure 4 also illustrates the gradual slowdown in production following the peak production years of 1997 and 1998, and the inverse relationship between production and commercial gas prices.

We note that while the commercial price of gas peaked in 2006, the spot price for natural gas peaked in 2008 at $9.16 per Mcf (thousand cubic feet at 14.73 psi) yet dropped sharply to $4.66 per Mcf a year later. The 2012 spot price for natural gas was even lower at $2.81 per Mcf.

Spot prices determine industry development, and the decline has clearly affected well activity. Figure 5 plots the number of permitted, drilled, reworked and plugged wells for the 2000 to 2010 period, along with the Michigan spot price.

As Figure 5 shows, new well development in the industry is price sensitive. The number of permitted and drilled wells in Michigan increased, albeit unevenly, up to the 2006 to 2008 period. This was the time when spot prices peaked. Likewise, the rapid decline in new well activity afterward corresponds with a sharp drop in spot prices. Instead of drilling new wells, producers have sought to sustain industry activity by taking the less expensive option of reworking existing wells. Nonetheless, new well development in Michigan is necessary to reverse the decline in natural gas production depicted in Figure 4.

Industry employment appears to be less sensitive to spot prices. Figure 6 provides QCEW job counts in two NAICS three-digit categories for all of Michigan: Oil and Gas Extraction (NAICS 211) and Support Activities for Mining (NAICS 213).

Employment in NAICS 211 would include the main producers of natural gas; employment in NAICS 213 includes all the specialty contract labor needed for well development, such as for drilling and hydraulic fracturing. Firms supplying support services employ approximately three times as many persons as main producers. As Figure 6 illustrates, employment among the main producers is less sensitive to new well development than employment with firms providing support services.

Michigan employment in oil and gas development (NAICS 211) and oil and gas support services (NAICS 213) peaked in the 2006 to 2008 period at about 2,500 FTE when gas well development was comparatively high. The drop in employment in 2009 was almost exclusively absorbed by support services; the 2008 to 2009 employment decline for producers (NAICS 211) was 1.7 percent versus 15.9 percent for support services (NAICS 213). Support services recovered roughly 60 percent of the 2009 employment losses by 2011. This employment recovery is probably due to the rising price and exploration for oil.

Recall that the QCEW data categories NAICS 211 and NAICS 213 include employment in natural gas and oil extraction. In Michigan, about 19.9 percent of active wells in the 2001 to 2011 period were for oil, located primarily in southern Michigan. If one assumes that the labor requirements for extracting oil is comparable to the labor requirements for extracting natural gas, then the QCEW job counts in Figure 6 can be reduced proportionately to arrive at an estimate for the employment in Michigan attributable to the natural gas industry. Making these adjustments, we estimate that natural gas production (NAICS 211) is associated with an annual average of 443 FTE over the period, ranging from a high of 474 (in 2010) to a low of 394 (in 2002). Statewide employment in support services (NAICS 213) averaged 1,350 FTE over the period, with a range of 1,566 (in 2008) to 1,191 (in 2002).

Compensation offers yet another perspective on employment. Figure 7 presents the trend in inflation-adjusted (2012 figures) annual salaries for employees in NAICS 211 and NAICS 213.

Jobs in either NAICS category provide gainful employment, and salaries are rising faster than inflation. Median household income for Michigan averaged $48,669 over 2007 to 2011. By comparison, the average salary for persons employed in NAICS 211 and NAICS 213 was $81,241 and $64,354, respectively, over those same years. These salary figures are especially large for rural counties in the north-central region of Michigan where household incomes tend to be below-average for the state.

Employment with oil and gas producers (NAICS 211) is more lucrative than employment with the support industries (NAICS 213), averaging 22.3 percent higher salaries from 2001 to 2011. And the gap is growing, averaging 13.8 percent in 2001 to 2004 and rising to 28.1 percent in 2008 to 2001. As with the employment counts, the salary figures suggest that industry support employees are the hardest hit when the industry contracts.

Figure 6: Michigan Oil and Gas Industry Employment (Full Time Equivalent) Trend

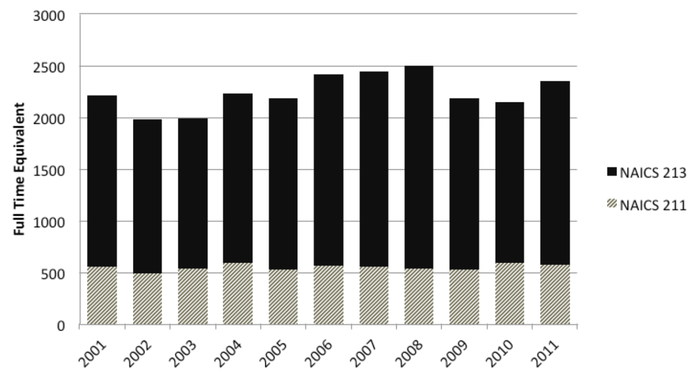


Figure 7: Michigan Oil and Gas Industry Average Salary Trend

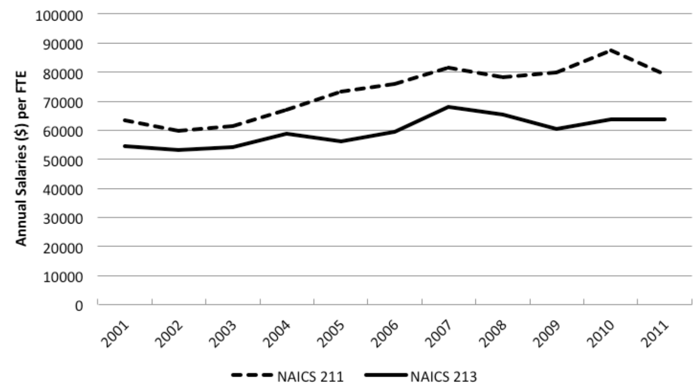
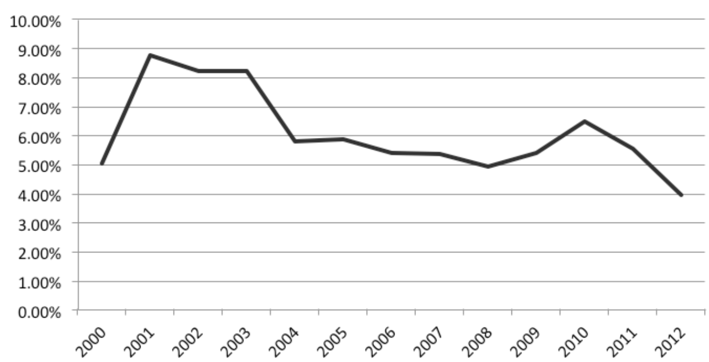


Figure 8: Nationwide Independent Contract Labor in Oil and Gas Industry



One limitation inherent in the QCEW payroll figures is the ability to quantify the use of contract labor in an industry. The Current Population Survey (CPS), administered by Bureau of Labor Statistics and the Census Bureau, classifies respondents by the industry they are employed in and whether they are self-employed contractors (versus employees of a private establishment, public service, or other). Drawing from this data, Figure 8 plots the nationwide percentages of persons working in the NAICS 211 and NAICS 213 categories that claim self-employed, independent contractor status. Figure 8 indicates that approximately 4 to 8 percent of respondents in the gas extraction industry self-describe as independent contractors. Our projections should include an adjustment to account for these industry actors.

The gas extraction industry and labor market in Michigan can be summarized as follows. The industry is extremely sensitive to the spot market price for natural gas, and has the capacity to quickly expand or contract in response to fluctuations in prices. When it is economically feasible to drill new wells, teams of workers with

TABLE 3: Michigan Department of Natural Resources Revenues ($1,000)

	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012
Royalties	69,519	56,187	68,516	41,890	29,119	25,131	18,367
Bonuses & Rent	4,879	2,716	16,573	6,427	180,383	12,707	7,698
Storage	63	141	113	86	446	154	137

Source: Minerals Projection Report, Department of Natural Resources, Minerals Management Section, Lansing, Michigan, January, 2013

TABLE 4: Michigan Treasury Revenues ($1,000)

	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010
Severance Tax[a]	87,809	68,143	101,232	55,036	58,277
Privilege Fee[b]	7,781	7,298	13,126	7,333	3,108

Source: Annual Report of the Michigan State Treasurer for Fiscal Year (FY) 2009-2010, Taxes and Fees Collected p. 19. Notes: (a) These estimates are for oil and gas combined. The 2010 severance revenue for gas only was 32.6 million. (b) The privilege fee is also known as the surveillance fee.

varied skills are hired for short-term work assignments performing labor-intensive development tasks. Once the well is producing, the demand for labor drops precipitously. Consequently, much of the industry employment is precarious.

Michigan has a relatively stable group of core jobs with gas producers (NAICS 211), where the salaries are substantially above average for the region. Yet the number of FTE in NAICS 211 is comparatively small when matched against support activity (NAICS 213) employment. Support industries employ three times more persons than immediate gas producers. Independent contractors are estimated at 4 to 8 percent of industry employment.

Precarious employment is consistent with the "boom" and "bust" nature of this industry. New well development requires substantially more labor than post-drilling gas production and system maintenance. Consequently, support industries bear the brunt of job loss when gas development declines. Jobs with gas producers provide the highest compensation in the industry and appear to be relatively buffered from the vicissitudes of the natural gas market.

2.2 Royalties, Taxes, and Fees to the State of Michigan

There are three main categories of revenue received by the State of Michigan from gas extracted on State property: royalties, fees, and taxes. Royalties are calculated at one-sixth of the gross revenue from gas sales. There are, however, a few exceptions. Wells on State property prior to 1981 pay one-eighth royalty. Further, there are some leases in known development areas that pay three-sixteenth royalty. On occasions where wells are developed but unable to produce due to the lack of a gathering line or maintenance shut down, the well owner pays an amount equal to rent.

Bonus payments are received for the right to obtain a lease for exploration on State property, and are arrived at by auction and direct negotiation. Rent payments are the right to establish a well pad on State property. Typical for both is a 5 year term to give the producer an opportunity to explore the well-area potential.

The State receives payments for the storage of gas underground for later use. Revenue for these three types of sources from 2006 to 2012 is in Table 3.

The correlation between industry activity and royalties is evident from these statistics. FY 2012 royalties are less than one-third of what the State earned during the peak years of 2006 to 2008. Bonuses and rent are a function of auction activity, and therefore less stable. FY 2010 was an anomalous year when speculation by several large developers escalated auction prices. Since then, bonuses and rent levels have retreated to the pre-FY 2010 magnitudes. Storage fees are a small fraction of the total revenues.

Natural gas extracted from private land is subject to two Michigan income taxes. First is the severance tax, which in 2012 was 5 percent. The severance tax rate is adjusted statutorily and therefore comparatively stable over time. Second is the privilege tax which is collected to pay for the DEQ regulation activities. The privilege tax is collected annually by Office of Oil and Gas and the Treasury, and it is adjusted annually. The privilege tax rate was 0.0029 percent in 2010. There is also a permit fee of $300 per new well, which is sent to the Treasury and is used to support DEQ regulatory activities. Table 4 provides the historic figures for Michigan tax revenues from gas and oil extraction:

A large share of royalty payments, bonuses, and rental fees finance State land development. The Department of Natural Resources

(DNR) refers to these as "mineral revenues," which by statute are earmarked to fund the Michigan Natural Resources Trust Fund.[vii] The purpose of the trust is to finance improvements on Michigan land for recreational use and to protect scenic areas. When the maximum funding level for the trust is reached ($500 million), the surplus is allocated to the Michigan State Parks Endowment Fund.[viii] Remaining revenues are allocated to the Michigan Game and Fish Protection Fund, and finally, to the State general fund.

Drilling on State property is regulated by both the DNR and DEQ. The DNR determines the development potential of an area based on best use for the state. For instance, the area below the surface of the Great lakes is classified as "non-leasable," which includes prohibitions against directional drilling. Other areas, categorized as "non-development," prohibit surface disturbance yet allow for directional drilling into the substrata. Other areas allow for development on the surface but with specific restrictions for addressing some aspect of the natural environment, such as accommodations for endangered species. Finally, the least restricted classification allows for surface development under a standard set of environmental constraints. The DEQ inspects wells and performs environmental and water withdrawal assessments to ensure compliance with Michigan law and minimize negative environmental effects from drilling, production, and wastewater disposal.

2.3 Royalties and Leases to Private Landowners

Owners of mineral rights receive royalties from the natural gas extracted from their property. Royalty payments are typically structured as a share of gross revenue, and thus producers and mineral rights owners share the risk and rewards that come with the uncertainty of well productivity and market changes in natural gas prices.

For private mineral rights owners, royalty amounts are negotiated, but a value of one-eighth of proceeds is common. When the resource play involves more than one landowner, the royalties are divided in proportion to geographic area. Private mineral rights owners will frequently negotiate a signing bonus for the right to drill and explore the potential of the play, but higher signing bonuses typically reduce the royalty fraction. Above ground, the landowner that leases the site for the well pad will typically receive additional lease payments.

Royalty and lease payments to private mineral rights owners were estimated at $81.5 million in 2010. This figure was arrived at by taking the state royalty tax amount for 2010, $32.6 million (see Table 4, note a), dividing by the tax rate of 5 percent to arrive at a total value of gas obtained from private land, and then assuming a royalty average of one-eighth of gross revenue for private mineral rights owners.

2.4 Land Values

Natural gas extraction affects property values. Whether a property asset increases or decreases in value depends on if a landowner is positioned to earn royalties or lease payments. In general, owners of productive mineral rights will experience a gain in property values, at least while resources exist and assuming that the extraction process does not impart long-term negative consequences, such as groundwater contamination. Landowners without promising mineral rights in the vicinity of industry activity that might be affected by environmental factors, such as noise, air pollution, truck traffic and risk of water or ground contamination will experience a decline in property values. Public perceptions of the risks of hydraulic fracturing are almost certainly a determinant of the value loss.

Boxall, Chan, and McMillan[3] examine the effect of oil and gas well proximity on the value of homes in Alberta, Canada, 1994 to 2001. Using a hedonic model with spatial error adjustment (N=532), they conclude a decline in value of 4 to 6 percent for homes within a 4 km radius of a wellhead. The effect was statistically significant for wells with negative sensory attributes, such as sourwells (wells emitting high H2S) and flaring wells.

Muehlenbachs, Spiller, and Timmins[4] examine the effect of permitted and drilled gas wells on property in Washington County, PA, 2004 to 2009. Muehlenbachs et al.[4] apply several methods, but the most innovative was a comparison of the property values of homes that rely on public water systems (and thus are protected from groundwater contamination) and homes that were dependent on private wells. The researchers concluded that homes with public-water systems within a 2 km distance experienced a gain in value of 10.7 percent due to the potential for royalty revenue. However, the groundwater-dependent homes experienced no net gain, and perhaps even a loss in value of 12.9 percent.

Neither team of researchers uses lease payments to homeowners, nor the ownership of mineral rights, as a variable that predicts property values. Yet industry practice suggests that the positive effects on land values are nearly always contingent on mineral rights. Owners of mineral rights potentially earn royalties from extracted gas, but for surface landowners that do not have mineral rights, but sit above or near resource plays, gas extraction in the vicinity is likely to be a liability.

Consequently, sales of land above resource plays often involve negotiations over mineral rights. Sellers will seek a premium for transactions that include mineral rights, while buyers will seek price

vii. Michigan Constitution of 1963, Section 35.

viii Natural Resources and Environmental Protection Act of 1994, Section 324.1902.

discounts if the owner retains mineral rights. Sharing mineral rights is occasionally the solution, whereby a seller retains some fraction of mineral rights.

3.0 CHALLENGES AND OPPORTUNITIES

Kinnaman[5] asserts that research to date has yet to convincingly quantify the effects of industry expansion on employment. And indeed, peer-reviewed research on the topic is scarce. Weber[6] begins to fill this gap by comparing county-level gas production with changes in employment, wage income, household income, and poverty in a group of "boom" and "non-boom" counties in Wyoming, Colorado and Texas over the 1993 to 2007 period. Depending on the empirical model, Weber reports positive gains in employment, wage income, and household income associated with increased gas production. No significant reduction in poverty was found, implying that few of the wealth gains reached lower socio-economic citizens. Importantly, the estimated employment gains from Weber's analysis were substantively lower than employment projections from prior input-output studies.

3.1 Employment Overestimation in Input-Output Studies

MSETC[2] provides perhaps the most detailed descriptions of the workforce requirements for gas extraction. The methodology begins by estimating the types and numbers of workers needed to drill a single gas well in the Marcellus region, and then arrives at a total workforce estimate by extrapolating based on projected drilling.

A report commissioned by New York State used the MSTEC estimates for the baseline crew needed to drill a single well, and then extrapolated out the direct and indirect employment using multipliers from the BEA based on low, medium, and high production levels[7].

There is reason to believe that both studies overestimate the industry effects on employment. One potential flaw resides in the initial baseline estimate for well development. If the initial baseline FTE per well is overstated, then so will any extrapolated figures or multiplier-based projections. A second possible flaw is in the assumptions regarding the relationship between industry activity and employment. We expect a positive relationship, however the elasticity of demand for employment with respect to industry activity should be much less than one. The approach used by MSETC assumes a perfectly linear, positive relationship between gas well-development and jobs[2]. A final limitation in earlier analyses is the neglect of a possible displacement effect by industry activity. Specific reasons for skepticism are:

1. As described in Table 1, the industry develops wells by hiring crews for limited periods of time. The drilling phase, which involves the largest number of persons, can be as short as a week. Once a well is producing, annual maintenance only requires a fraction of an FTE per well. Afterward, the only time a sizable crew is needed (other than during an emergency) is when the well is plugged, which can occur decades after the original drilling. Thus, to annualize the FTE baseline figures for well development the crew size estimates need to be proportionately reduced by the fraction of annual time on a single site. It is unclear whether prior research performed this standardization.

2. It is unknown the extent that the labor hired for well development is local, i.e. Michigan-based, versus from other states. As Figure 4 above illustrates, approximately half of the production is from out-of-state firms. It is quite plausible that these firms bring in crews from out-of-state, especially to handle industry-specific technical tasks. Even Michigan-based developers might seek the skills of out-of-state specialists. Projections that fail to distinguish between in-state and out-of-state FTE will overstate the effects of industry development on local employment.

3. Employment "stickiness" is the tendency for firms to resist discharging employees when commercial activity contracts to protect against the loss of firm-level knowledge and training investments. Similarly, firms that experience an industry boom usually do not immediately expand hiring, but instead accommodate new business with the existing workforce or contract labor until anticipated growth warrants permanent new hires. This is how businesses minimize recruitment and training costs and avoid severance expenses should the boom be short-term. As such, employment rarely expands and contracts in exact proportion to the changing industry demand. A more accurate technique is to estimate the incremental employment change that accompanies the change in some unit of industry activity.

4. A displacement effect has not yet been tested. While some businesses directly benefit from gas extraction (e.g. industry suppliers), and others gain from increased commercial activity (e.g. hotels), other business might suffer losses by gas extraction activity (e.g. industries involved in recreation and tourism).

3.2 Michigan Employment and Gas Extraction Activity

Our intent is to contribute to this research stream by estimating the job impact of natural gas extraction in Michigan. To conceptualize the employment effects of industrial activity, it is useful to first distinguish between direct, indirect, and induced job creation and compensation. Direct job effects are defined as the employment and compensation within the gas extraction industry. For our purposes, estimates for direct employment are derived from QCEW data in two NAICS three-digit categories: Oil and Gas Extraction (211) and Support Activities for Mining (213).[ix] Our analysis begins with an estimate of the relationship between gas extraction activity (i.e. well development and gas production) and direct employment.

Indirect employment is defined as the job creation through inter-industry linkages. Expanding activity in one industry will increase the demand for products and services of suppliers, which in turn will have positive effects on employment across the supply chain. Our estimate for indirect employment will be derived by applying our direct industry employment estimates to multipliers from the Regional Input-Output Modeling System (RIMS II) supplied by the Bureau of Economic Affairs for the State of Michigan[8].

Induced employment is defined as the regional increase in jobs caused by the general growth in wealth and income. When an industry expands jobs and income in a region, aggregate consumer demand for items related to food, housing, transportation, public services, and so forth will also expand. Induced employment is the resultant gain in employment in local private businesses and in the public sector. Moreover, because the gas extraction industry provides a critical input for many manufacturing processes, there is the possibility that gas-dependent industries will shift or relocate employment to Michigan if domestic gas production creates a stable and low cost supply of natural gas. This is another form of induced employment that we discuss in the section titled "Prioritized Pathways for Phase 2."

Displacement effects from the natural gas extraction industry, i.e. where an increase in drilling and production reduces employment in other industry sectors, subtract from the induced employment amounts. Tourism and farming might be negatively affected by industry activity. No prior study that we are aware of has tested for displacement effects.

One challenge in estimating induced employment is to avoid overlapping with the estimates for indirect employment. Indirect employment is caused by industry consumption of necessary product or service inputs (i.e. the supply chain); induced employment is from the consumption by employees in the industry that receive a paycheck. In the case of gas extraction, we also consider the positive job creation attributable to a reliable and low-cost supply of a critical manufacturing input as an induced effect. Unfortunately, there is no clear identifier in the data for whether a job is part of the supply chain, so there is a potential double-counting problem.

A partial solution is to restrict the estimates for induced employment effects to the county in which the economic activity occurs. Indirect employment, in contrast, will be estimated at the state level. The key assumption here is that the effect of industry consumption (through a web of suppliers) is geographically larger than the more localized effects caused by industry employee consumption. We believe this assumption is reasonable; however the solution is partial because some industry suppliers will be located within the same county where the economic activity takes place, and thus included in both the indirect and induced counts. To the extent that this occurs our analysis will overstate induced employment effects.

3.3 Data and Empirical Model

To estimate the relationship between direct industry employment and industry production we match QCEW job counts in NAICS 211 and 213 with gas production and well-development data obtained from the DEQ.

Our objective is to make full use of the county-level, longitudinal data for capturing spatial effects of industry activity on direct employment. We model direct industry employment growth as a function of gas production and well development, where gas production is in annual MMcf and well development is the annual number of new or reworked wells. Our county-level analysis assumes two potential areas for economic activity: (1) where the firm resides and (2) where gas is extracted.[x] To capture the full spatial effects of industry activity, gas production and well development are included for firm and extraction locations. Thus, the change in county-level direct industry employment, Y, is a function of:

1. Gas production based on firm location; GF
2. Gas production based on extraction location; GE
3. New wells based on firm location; NF
4. New wells based on extraction location; NE
5. Reworked wells based on firm location; RF
6. Reworked wells based on extraction location; RE

The estimating equation is in log-linear form:

$$Y_{it} = \alpha+\beta(\Delta GF)_i+\beta(\Delta GE)_i+\Sigma\beta NF,NE,RF,RE)_{it}+\Sigma\beta(NF,NE,RF,RE)_{it-1} +\Sigma\beta(Year)+\mu_i +\varepsilon_{it}$$

Where Y_{it} = ln [FTE +1] for each NAICS 211 and NAICS 213 in county i and year t; α is the model intercept; ΔGF is the year over

ix. The QCEW data are a quarterly headcount of employed persons covered by state or federal unemployment insurance. Since these headcounts include employees that are less than full-time, as well as employees working overtime, the figures are not strictly full time equivalents (FTE). We nonetheless use the term "FTE" throughout for the sake of brevity.

x. As Figures 1 and 2 indicate the two locations do not perfectly coincide.

year change in firm-location gas production; ΔGE is the year over year change in extraction-location gas production; $(NF,NE,RF,RE)_{it}$ are new and reworked wells for time t; $(NF,NE,RF,RE)_{it-1}$ are lagged new and reworked wells; Year are dummy variables each year in the sample; β are slope coefficients; μ_i are random county intercepts; and ε_i are random disturbances.

The longitudinal data provides several advantages. First, we include lagged well development measures to capture employment effects in the contemporaneous and following year. Second, the data allow for year controls to factor out unmeasured annual effects on employment. Finally, panel data allow the use of random county intercepts controls for unmeasured regional traits.

Our analysis is limited to Michigan counties where some industry-related economic activity is taking place. We omitted counties when the joint conditions are all true for all time periods: no employment in NAICS 211, no employment in NAICS 213, no new gas wells, no reworked gas wells, and no extraction location or firm location gas production. A total of 13 Michigan counties met these criteria. Our final sample includes the remaining 70 counties.

Table 5 displays the summary statistics for the variables.

TABLE 5: Variables and Statistics (N=630)

Variable Name	Mean	s.d.	Source
Employment FTE 211 (t)	7.756	17.463	QCEW
Employment FTE 213 (t)	23.038	57.384	QCEW
New Well –Extraction (t)	15.081	41.279	DEQ
New Well – Extraction (t-1)	15.717	42.317	DEQ
New Well – Firm (t)	10.210	61.346	DEQ
New Well – Firm (t-1)	10.650	61.841	DEQ
Old Well – Extraction (t)	9.321	15.185	DEQ
Old Well – Extraction (t-1)	9.313	14.719	DEQ
Old Well – Firm (t)	5.169	17.606	DEQ
Old Well – Firm (t-1)	5.063	16.690	DEQ
Δ Gas Production - Extraction	-146.297	666.450	DEQ
Δ Gas Production - Firm	-72.385	632.554	DEQ

Key: QCEW = Quarterly Census of Employment and wages; DEQ = Michigan Department of Environmental Quality

The data cover 70 counties over 10 years for a sample size of 700. Variables named "New Well" refer to newly drilled gas wells; variables named "Old Well" refer to reworked gas wells. Mean values for employment in FTE 211 and FTE 213 reflect the relative numbers of jobs in Michigan for these classifications (see Figure 6 above). Average jobs over the time period for the whole state can be arrived at by multiplying the mean values by 70, the number of counties.

TABLE 6: Gas Industry Employment and Industry Activity, 2001 to 2010

	NAICS 211	NAICS 213
	β (s.e.)	β (s.e.)
New Well – Extraction (t)	-0.000 (0.001)	-0.001 (0.002)
New Well – Extraction (t-1)	-0.000 (0.001)	-0.002 (0.002)
New Well – Firm (t)	0.002 (0.001)	0.002 (0.001)
New Well – Firm (t-1)	0.001 (0.001)	-0.001 (0.002)
Old Well – Extraction (t)	-0.001 (0.003)	0.003 (0.004)
Old Well – Extraction (t-1)	0.001 (0.003)	0.006 (0.004)
Old Well – Firm (t)	-0.000 (0.004)	0.013 (0.005)*
Old Well – Firm (t-1)	-0.001 (0.003)	-0.005 (0.005)
Δ Gas Production - Extraction	-0.000 (0.000)	0.000 (0.000)
Δ Gas Production - Firm	0.000 (0.000)	0.000 (0.000)
Year 2002	-0.097 (0.096)	0.061 (0.135)
Year 2003	0.003 (0.096)	0.178 (0.135)
Year 2004	0.009 (0.096)	0.234 (0.134)
Year 2005	0.011 (0.096)	0.228 (0.135)
Year 2006	0.020 (0.096)	0.266 (0.135)*
Year 2007	0.101 (0.096)	0.303 (0.135)*
Year 2008	0.124 (0.097)	0.234 (0.135)
Year 2009	0.125 (0.098)	0.225 (0.138)
Year 2010	0.164 (0.096)	-0.016 (0.135)
Constant	0.987 (0.162)**	1.393 (0.191)**
- Log Likelihood	726.548	948.312
Counties	70	70
Observations	700	700
* $p < 0.05$; ** $p < 0.01$		

For all employment and well variables, a comparison of the contemporaneous (t) and lagged (t-1) means tells whether the statistic has increased or decreased over time; where t is greater than t-1 there has been an increase in the measure, and vice versa. A cursory review of mean values for "New Well" along with the change in gas production indicates that industry activity has slowed during the decade. Declines in new drilling have been partially offset by "Old Well" reworking.

3.4 Regression Results

Table 6 provides the regression results estimating employment change in NAICS 211 and NAICS 213 for Michigan.

The regression results in Table 6 yield indicate a weak relationship between industry activity and industry employment. Coefficient estimates, which give the marginal elasticity of employment in relation to the independent variables, are small in magnitude, and only breach standard levels of statistical significance in the case of reworked wells and employment in NAICS 213. A single reworked well raises employment in support services by an estimated 1.3 percent.

Results from Table 6 can be converted to the marginal change in FTE for both NAICS groups by summing the coefficient estimates for the two spatial areas of economic activity, well location and firm location, and then multiplying by the mean employment values in Table 5. The estimates are presented in Table 7.

Corroborating the trends in Figure 6, employment in NAICS 213 is more sensitive to gas well development than employment in NAICS 211; the differences in the magnitudes of FTE are much larger for NAICS 213. A new well is associated with a negligible FTE change for NAICS 211, but a 0.022 FTE gain for NAICS 213 in the year the well is drilled. A year later the year-old well is associated with a decline of 0.082 FTE for NAICS 213, reflecting the employment loss once the drilling phase is completed.

For NAICS 211, the changes are comparably small; however it is notable that contemporaneous and lagged FTE change is positive for new wells and negative for reworked wells. This might be a reflection of industry health; new wells signal expansion and growth, while reworked wells are indicative of retrenchment.

Reworked wells have a larger effect on employment than new wells. Once again, the effect on employment in category NAICS 211 is negligible (in Table 6 statistically indistinguishable from zero); however, in the contemporaneous year, a reworked well adds an estimated incremental gain of 0.371 new FTE for NAICS 213. To put this in perspective, this figure can be annualized to a job-site statistic. Assuming the average well rework takes one month, the 0.371 estimate can be multiplied by 12; the sum of which is 4.45, or about the size of a crew.

We offer two hypotheses for why the estimated effects of reworked wells on employment are higher than for new wells. First, the finding may be capturing a strategy by firms to tap gas deposits from existing wells at a time when spot prices are dropping and drilling new wells is cost prohibitive. Firms that turn their attention toward reworking older wells will deploy labor to these tasks and on average retain more employment. Second, gas development from reworked wells may use a greater amount of local labor than for new wells, whereas new drilling might demand skills that necessitate hiring labor from outside Michigan.

Results from Table 6 also indicate a weak relationship between gas production and employment for both NAICS categories. The coefficient for gas production change fails to breach standard levels of statistical significance for employees classified in NAICS 211 and for employees classified in NAICS 213.

3.5 Results: Indirect Employment

Direct FTE estimates from Table 7 are used to project indirect FTE estimates using coefficients supplied by the BEA. The multiplier coefficient for NAICS 211 was approximately 0.355, while the same coefficient for NAICS 213 was approximately twice as high at 0.642. The difference in these BEA coefficients is further

Figure 9: Indirect Multipliers for Oil and Gas Extraction Industry in Michigan

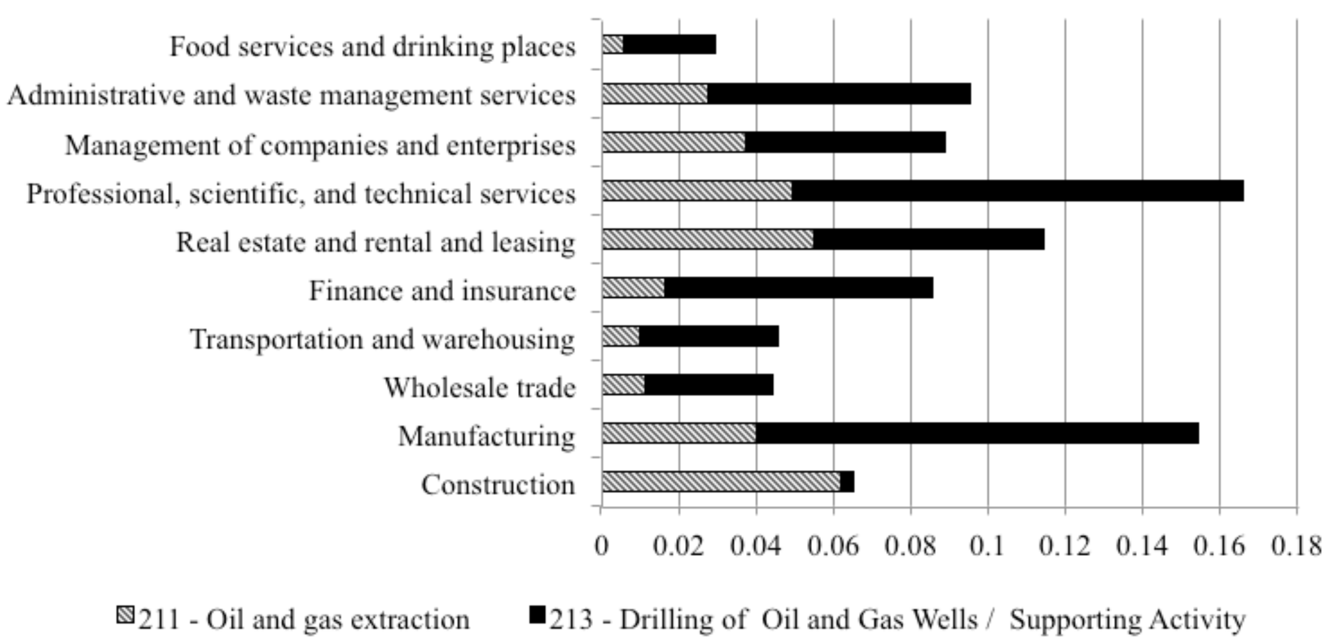


TABLE 7: Predicted Incremental Direct FTE based on Well Development

	NAICS 211		NAICS 213	
	New Well	Reworked Well	New Well	Reworked Well
Contemporaneous (t)	0.008	-0.007	0.022	0.371
Lagged (t-1)	0.005	-0.002	-0.082	0.024

evidence that employers in the gas extraction service sector are more reliant on Michigan-based production inputs than employers in gas extraction. Figure 9 illustrates the sources and magnitudes of inputs for NAICS 211 and NAICS 213.

As a whole, the industry draws heavily from firms that provide professional, scientific, and technical services, as well as manufacturing. The coefficients also reflect the need for services dealing with land procurement, remediation, waste management, construction, transportation, insurance, and general management.

Per well indirect FTE estimates are arrived at by multiplying the direct employment estimates in Table 7 (for the contemporaneous period) by the BEA industry multipliers for Michigan. For each new well the indirect FTE is estimated at 0.017 (0.008 * 0.355 + 0.022 * 0.642) and for each reworked well the indirect FTE is estimated at 0.236 (-0.007 * 0.355 + 0.371 * 0.642).

3.6 Results: Induced Employment From Direct Industry Jobs

Our test for induced employment examines the change in regional level employment caused by a regional change in direct industry employment. Induced employment estimates were calculated by performing regressions as per the equation below for the major two-digit NAICS groups, excluding industries in NAICS 21.

$$Y_{it} = \alpha+\beta(\text{NAICS }211)_{it}+\beta(\text{NAICS }213)_{it}+\beta(\text{NAICS }211)_{it-1}+\beta(\text{NAICS }213)_{it-1} +\Sigma\beta(\text{Year})+\mu_i +\varepsilon_{it}$$

Where Y_{it} is the natural log for the FTE for an NAICS two-digit group in county i and year t; α is the model intercept; NAICS 211 is the employment in NAICS category 211; NAICS 213 is the employment in NAICS category 213; Year are dummy variables each year in the sample; β are slope coefficients; μi are random county intercepts; and μ_i are random disturbances.

Marginal estimates for employment change due to a unit change in direct industry employment were calculated for the industry categories listed in Table 8 (see appendix for results). Induced employment estimates based on new well and reworked wells was arrived at by multiplying the estimated FTE gains from Table 7 with the computed slope coefficients (i.e. β above).

For most two-digit NAICS groupings, the estimated coefficients were not statistically different from zero, so it is important to be careful when generalizing from the numbers in Table 8. The estimated values presented in Table 8 are derived from all equation coefficients, regardless of statistical significance. Regression results for the various industries are in the appendix.

New wells appear to have a higher overall induced employment effect than reworked wells. The total induced estimate for new wells is 0.862 (0.059 + 0.803) versus 0.147 (0.388 – 0.241) for reworked wells. These sums are speculative given the multi-layered approach to this analysis, and the level of uncertainty that accompanies each statistical model. What the analyses may be capturing, however, is the extent of industry expansion. New drilling signifies growth and investment more so than the reworking of existing wells.

It is possible to take any single industry category to obtain a sense for whether well development displaces jobs. An estimate that is negative in periods t and t-1 would suggest a displacement possibility (or at least no net gain). Table 8 also provides a sense for whether induced job gains are short or long-term. Positive values in time t and negative values in t-1would suggest that the induced job gain is short-lived. Negative values at t and positive values at t-1 indicate a lagged positive effect that might extend into subsequent periods.

3.7 Summary FTE Estimates

Table 9 summarizes the estimates for direct employment, indirect job effects, and induced job effects for several production scenarios in Michigan. Choosing a “low” and “high” level of industry activity is arbitrary for any simulation. To keep the projections within a realistic range our “low” and “high” scenarios assume a 50 percent drop and gain in new and reworked wells, respectively, from the decade average and that gas production holds steady. A 50 percent decrease in the number of new wells is a value of 523; a 50 percent increase in the number of new wells is 1,569. A 50 percent decrease in reworked wells is a value of 331; a 50 percent increase in reworked wells is 992.

The per well FTE estimates and employment change under low and high levels of well activity are summarized in Table 9.

TABLE 8: Induced Employment Estimates Based on 1 Well Project

Industry (two-digit NAICS)	New Well (t)	New Well (t-1)	Reworked Well (t)	Reworked Well (t-1)
Agriculture, forestry, fishing, and hunting	0.003	-0.013	-0.004	0.004
Utilities	0.011	0.003	0.060	-0.001
Construction	0.002	0.003	-0.308	-0.002
Manufacturing	-0.077	0.538	-0.617	-0.159
Wholesale trade	-0.012	0.012	-0.177	-0.002
Retail trade	0.054	-0.041	0.845	0.014
Transportation and warehousing	-0.017	0.041	-0.247	-0.012
Information	0.035	0.078	0.323	-0.025
Finance and insurance	-0.020	0.004	-0.341	-0.002
Real estate and rental and leasing	0.025	0.040	0.190	-0.012
Professional, scientific, and technical services	-0.097	-0.145	-1.371	0.040
Management of companies and enterprises	-0.023	0.032	-0.170	-0.010
Administrative and waste management services	0.104	0.102	1.260	-0.032
Educational services	-0.021	-0.096	-0.403	0.028
Health care and social assistance	0.059	0.067	0.589	-0.021
Arts, entertainment, and recreation	-0.012	-0.014	0.031	0.006
Accommodation, Food and drinking places	-0.045	0.022	-0.531	-0.007
Other services	0.018	0.001	0.235	-0.001
Public administration	0.070	0.170	1.022	-0.047
Total	0.059	0.803	0.388	-0.241

TABLE 9: Direct, Indirect and Induced FTE per Well and Under Low and High Well Development Scenarios

	New Wells		Reworked Wells	
Per Well Direct FTE	0.030		0.364	
Per Well Indirect FTE	0.017		0.236	
Per Well Induced FTE	0.862		0.147	
	Low	High	Low	High
Δ Direct FTE	15.7	47.1	120.5	361.1
Δ Indirect FTE	8.9	26.7	78.1	234.1
Δ Induced FTE	450.8	1,352.5	48.7	145.8
Δ Total FTE	475.4	1426.2	247.3	741.0

3.8 Limitations of this Study

At the beginning of this section we outlined the reasons why prior employment estimates for the effect of natural gas extraction were likely overstated. In this section we explain the reasons why our regression-based estimates might have missed the mark. Several sources of "noise" arise from limitations in the data and analysis.

1. Our county-level QCEW data is an aggregate headcount of employees in each county. The analysis involved matching these employment numbers against county and firm industry activity. Ideally, however, we would have firm level data on employment to match against each firm's level of industry activity. This loss of precision will generally reduce the sensitivity of estimated relationship between the two measures.

2. The DEQ data linking firm location to new and reworked wells was based on producer firms (the companies responsible for the well), not service firms. Service firms could therefore be

located in counties other than where wells and producer firms are, and thus not precisely captured in the analysis associating well development to employment in the gas extraction service sector.

3. Contract labor is not captured by the QCEW. Our contract labor adjustments were based on estimates from the Current Population Survey, which covers all U.S. states. Given our information on the amount of gas extraction in Michigan by non-Michigan firms, it is reasonable to suspect that the use of independent contractors in Michigan is greater than the national average. If so, we underestimated employment in the independent contractor sector, and hence the overall employment effect from the industry.
4. The time periods we include in the analysis are the contemporaneous and lagged year. However, it is the case that job growth in an industry can have longer-term effects on induced employment, for instance, as jobs become stable and permanent, which leads to larger purchases like housing. Our limited time frame probably underestimates induced job effects.

5. Spatial overlap concerns the possibility for "double counting" jobs that are both in the same county as the industry activity (i.e. our induced employment) and are part of the industry supply chain (i.e. our state-level indirect employment). This would happen, for example, if a firm in NAICS 211 or 213 hired a supplier from the same county in which they reside, which is probable for services that incur high transportation costs. We lack the data to parse the state-level indirect FTE estimates from the induced FTE estimates. This limitation will tend to overstate induced job effects.

4.0 PRIORITIZED PATHWAYS FOR PHASE 2

A goal of this report was to outline promising research areas for Phase 2; six are below.

1. Jobs in the gas extraction industry feature above-average pay. A valuable Phase 2 project is to look beyond compensation to examine other job attributes. Research into the health effects on workers that engage in hydraulic fracturing might prove valuable (Basu, Bradley, McFeely and Perkins, this series). Mills, Newell and Johnson9 found a higher rate of testicular cancer among men employed in the gas extraction industry, but their work predates the advancements in hydraulic fracturing that now depend on a wider array of chemicals. Further study is needed to understand the occupational risks of exposure to the chemicals currently used in hydraulic fracturing in order to develop guidelines for minimizing worker occupational illness and injury.

2. Our findings suggest that a considerable amount of labor in the Michigan gas extraction industry is from out-of-state firms, especially for new well development. A potential Phase 2 research question, in two-parts, is to first estimate the level of direct industry employment that is imported from out-of-state. We would want to know the types of skills and capital hired by regional producers from outside of Michigan. This information can be used to estimate the level of industry activity needed to feasibly establish within-state capacity. Such a project might be useful for any "import substitution" strategy for State economic development.
3. The State of Michigan benefits financially from gas extraction. Less understood are the liabilities incurred from this industrial activity. The most significant potential liabilities are remedial costs associated with migration, spillage, or improper handling of fracture fluids[10]. A challenge for the Phase 2 reports is to determine whether funding is sufficient for covering these potential liabilities. This will require a risk assessment that estimates the probability of an environmental event and remedial costs.

4. An area of debate is the extent that hydraulic fracturing assists or impedes in the development of renewable energy resources, such as solar or wind power. Proponents of hydraulic fracturing maintain that the expanded development of natural resources will move the economy away from other carbon-based energy sources, such as oil and coal, and act as a bridge until such time that renewable energy sources are economically viable. Opponents argue that by lowering the price of natural gas, hydraulic fracturing undermines market incentives to develop renewable energy sources. A Phase 2 question is whether the investment in infrastructure and manufacture of renewable energy methods is affected by the price of natural gas, and by extension, hydraulic fracturing. Public and private investment in renewable energy can be modeled as a function of natural gas prices.

5. One unexplored question is the extent that low-cost natural gas in the region encourages a form of induced employment by promoting job retention (or growth) from industries that use natural gas as a major manufacturing input. Five export-oriented industries rank high in natural gas utilization: food manufacturing (NAICS 311), paper manufacturing (NAICS 322), chemical manufacturing (NAICS 325), plastics and rubber products manufacturing (NAICS 326), and nonmetallic mineral manufacturing (NAICS 327). A Phase 2 research project could track employment changes in these industries and compare the movement of jobs with the price of natural gas. Ideally, such a project will

draw from international data to capitalize on natural gas price variation across nations.

6. The topic of property values has not been examined in the Michigan context. Extant research suggests that the type and attribute of the well are important factors for landowners. A further contribution would be to distinguish between ownership of the surface land and ownership of mineral rights, or alternatively to link changes in ownership to lease offers. These research improvements can be designed for a Phase 2 research project that examines the question of hydraulic fracturing and property values in Michigan.

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TABLE A1: Gas Industry Employment Induced Effects

	NAICS 11	NAICS 22	NAICS 23
NAICS 211[t]	0.001 (0.001)	0.003 (0.002)	0.001 (0.001)
NAICS 213[t]	-0.000 (0.001)	0.001 (0.001)	-0.000 (0.000)
NAICS 211[t-1]	0.001 (0.001)	0.000 (0.002)	0.001 (0.001)
NAICS 213[t-1]	0.001 (0.001)	-0.000 (0.001)	0.000 (0.000)
2003	0.010 (0.047)	-0.013 (0.056)	-0.047 (0.024)*
2004	0.017 (0.047)	-0.000 (0.056)	-0.050 (0.024)*
2005	0.051 (0.047)	0.008 (0.056)	-0.081 (0.024)**
2006	0.015 (0.047)	-0.042 (0.056)	-0.119 (0.024)***
2007	0.019 (0.047)	-0.102 (0.056)	-0.215 (0.024)***
2008	0.036 (0.047)	-0.130 (0.056)*	-0.300 (0.024)***
2009	0.019 (0.047	-0.157 (0.056)**	-0.470 (0.024)***
2010	0.050 (0.047)	-0.187 (0.056)**	-0.494 (0.024)***
2011	0.093 (0.047)*	-0.159 (0.056)**	-0.435 (0.024)***
Constant	4.953 (0.155)***	4.560 (0.187)***	6.916 (0.155)***
LL	284.623	-364.370	144.895
N	700	663	700
* p < 0.05; ** p < 0.01; *** p < 0.001			

	NAICS 31-33	NAICS 42	NAICS 44-45
NAICS 211[t]	-0.001 (0.001)	-0.000 (0.001)	0.000 (0.000)
NAICS 213[t]	-0.000 (0.000)	-0.000 (0.001)	.0004 (0.000)**
NAICS 211[t-1]	0.001 (0.001)	-0.001 (0.001)	-0.001 (0.000)
NAICS 213[t-1]	-0.001 (0.000)*	-0.000 (0.001)	0.000 (0.000)
2003	-0.036 (0.025)	0.041 (0.040)	-0.034 (0.010)**
2004	-0.031 (0.025	0.045 (0.040)	-0.023 (0.011)*
2005	-0.026 (0.025)	0.051 (0.040)	-0.044 (0.010)***
2006	-0.063 (0.025)*	0.042 (0.040)	-0.067 (0.011)***
2007	-0.119 (0.025)***	0.065 (0.040)	-0.079 (0.011)***
2008	-0.182 (0.025)***	0.045 (0.040)	-0.105 (0.011)***
2009	-0.396 (0.025)***	-0.060 (0.040)	-0.149 (0.010)***
2010	-0.359 (0.025)***	-0.037 (0.040)	-0.162 (0.010)***
2011	-0.303 (0.025)***	0.004 (0.040)	-0.166 (0.011)***
Constant	7.905 (0.191)***	5.855 (0.214)***	7.765 (0.164)***
-LL	91.471	-210.749	655.924
N	700	700	700
* p < 0.05; ** p < 0.01; *** p < 0.001			

	NAICS 48-49	NAICS 51	NAICS 52
NAICS 211[t]	-0.000 (0.001)	0.002 (0.001)	0.000 (0.001)
NAICS 213[t]	-0.000 (0.000)	0.001 (0.001)	-0.000 (0.000)
NAICS 211[t-1]	-0.000 (0.001)	0.004 (0.001)***	0.001 (0.001)
NAICS 213[t-1]	-0.000 (0.000)	-0.001 (0.001)	0.000 (0.000)
2003	-0.022 (0.032)	-0.033 (0.042)	0.027 (0.019)
2004	-0.013 (0.032)	-0.061 (0.042)	0.039 (0.019)*
2005	0.039 (0.032)	-0.053 (0.042)	0.035 (0.019)
2006	0.067 (0.032)*	-0.055 (0.042)	0.027 (0.019)
2007	0.069 (0.032)*	-0.047 (0.042)	0.006 (0.019)
2008	0.069 (0.032)*	-0.088 (0.042)*	0.000 (0.019)
2009	-0.020 (0.032)	-0.162 (0.042)***	-0.034 (0.019)
2010	-0.034 (0.032)	-0.226 (0.042)***	-0.039 (0.019)*
2011	0.007 (0.032)	-0.250 (0.042)***	-0.050 (0.019)**
Constant	6.035 (0.180)	5.308 (0.196)***	6.101 (0.184)***
LL	-59.122	-228.462	284.359
N	700	699	700
* p < 0.05; ** p < 0.01; *** p < 0.001			

	NAICS 53	NAICS 54	NAICS 55
NAICS 211[t]	0.002 (0.001)	-0.001 (0.001)	-0.002 (0.004)
NAICS 213[t]	0.001 (0.001)	-0.001 (0.001)*	-0.001 (0.002)
NAICS 211[t-1]	0.001 (0.001)	0.001 (0.001)	0.001 (0.004)
NAICS 213[t-1]	-0.001 (0.001)	0.001 (0.001)	-0.000 (0.002)
2003	0.004 (0.041)	0.040 (0.040)	-0.056 (0.139)
2004	0.007 (0.041)	0.035 (0.040)	-0.097 (0.141)
2005	0.009 (0.041)	0.050 (0.040)	-0.112 (0.142)
2006	0.042 (0.041)	0.033 (0.040)	-0.128 (0.141)
2007	0.002 (0.041)	0.072 (0.040)	-0.163 (0.141)
2008	-0.052 (0.041)	0.028 (0.040)	-0.387 (0.143)**
2009	-0.134 (0.041)**	-0.043 (0.040)	-0.354 (0.142)*
2010	-0.183 (0.041)***	-0.026 (0.040)	-0.363 (0.141)*
2011	-0.233 (0.041)***	-0.031 (0.040)	-0.501 (0.140)***
Constant	4.929 (0.193)***	5.915 (0.225)***	4.432 (0.335)***
LL	-208.470	-205.774	-556.371
N	700	700	438
* p < 0.05; ** p < 0.01; *** p < 0.001			

TABLE A1: Gas Industry Employment Induced Effects continued

	NAICS 56	NAICS 61	NAICS 62
NAICS 211[t]	0.001 (0.002)	0.000 (0.000)	0.000 (0.000)
NAICS 213[t]	0.001 (0.001)	-0.000 (0.000)	0.000 (0.000)
NAICS 211[t-1]	0.001 (0.002)	-0.000 (0.000)	0.000 (0.000)
NAICS 213[t-1]	-0.000 (0.001)	0.000 (0.000)	-0.000 (0.000)
2003	0.058 (0.057)	0.001 (0.014)	0.035 (0.015)*
2004	0.110 (0.057)	-0.017 (0.014)	0.044 (0.015)**
2005	0.153 (0.057)**	-0.040 (0.014)**	0.082 (0.015)***
2006	0.121 (0.057)*	-0.073 (0.014)***	0.098 (0.015)***
2007	0.119 (0.057)*	-0.112 (0.014)***	0.130 (0.015)***
2008	0.094 (0.057)	-0.127 (0.014)***	0.134 (0.015)***
2009	-0.029 (0.057)	-0.153 (0.014)***	0.131 (0.015)***
2010	0.004 (0.057)	-0.189 (0.014)***	0.146 (0.015) ***
2011	0.196 (0.057)**	-0.220 (0.014)***	0.146 (0.015)***
Constant	6.040 (0.241)***	7.471 (0.171)***	7.543 (0.177)***
LL	-429.640	491.504	411.262
N	696	700	700
* p < 0.05; ** p < 0.01; *** p < 0.001			

	NAICS 71	NAICS 72	NAICS 81
NAICS 211[t]	-0.002 (0.001)	-0.000 (0.001)	0.000 (0.001)
NAICS 213[t]	0.000 (0.001)	-0.000 (0.000)	0.000 (0.000)
NAICS 211[t-1]	-0.004 (0.001)**	0.000 (0.001)	0.000 (0.001)
NAICS 213[t-1]	-0.000 (0.001)	-0.000 (0.000)	0.000 (0.000)
2003	-0.003 (0.039)	-0.010 (0.019)	-0.020 (0.019)
2004	-0.006 (0.039)	0.001 (0.019)	-0.001 (0.019)
2005	0.014 (0.039)	0.002 (0.019)	0.011 (0.019)
2006	-0.023 (0.039)	-0.008 (0.019)	0.000 (0.019)
2007	-0.034 (0.039)	-0.016 (0.019)	-0.014 (0.019)
2008	-0.078 (0.039)*	-0.039 (0.019)*	-0.016 (0.019)
2009	-0.149 (0.039)***	-0.064 (0.019)**	-0.035 (0.019)
2010	-0.179 (0.039)***	-0.064 (0.019)**	-0.041 (0.019)*
2011	-0.170 (0.039)***	-0.126 (0.019)***	-0.035 (0.019)
Constant	5.553 (0.177)***	7.418 (0.159)***	6.236 (0.174)***
LL	-177.985	275.473	266.945
N	700	700	700
* p < 0.05; ** p < 0.01; *** p < 0.001			

	NAICS 92
NAICS 211[t]	0.000 (0.001)
NAICS 213[t]	0.001 (0.000)***
NAICS 211[t-1]	-0.001 (0.001)
NAICS 213[t-1]	-0.001 (0.000)**
2003	-0.030 (0.022)
2004	-0.023 (0.022)
2005	0.119 (0.022)***
2006	0.124 (0.022)***
2007	0.108 (0.022)***
2008	0.118 (0.022)***
2009	0.124 (0.022)***
2010	0.121 (0.022)***
2011	0.075 (0.022)**
Constant	6.774 (0.142)***
LL	191.002
N	700
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$	