Changes in Crime Related to Marcellus Shale Development

The Marcellus Shale Impacts Study Wave 2: Chronicling Social and Economic Change in Northern and Southwestern Pennsylvania

March 2017

Executive Summary

The rapid increase in Marcellus Shale development in Pennsylvania over the past decade has raised questions as to whether there have been concurrent changes in rates of criminal activity. To date, preliminary research on the effects of Marcellus Shale development activity has found limited or mixed results linking criminal activity to well development (Brasier and Rhubart, 2014; Kowalski and Zajac, 2012), although some studies (Multi-State Shale Research Collaborative, 2014) and qualitative data (Davis et al., 2014) suggest a relationship, at least in some communities. In addition, few longitudinal analyses – to examine the changes in crimes over time in direct relation to well development – have been conducted on this topic in the Marcellus Shale region. This research used publicly available data to examine the relationship between Marcellus Shale development and crime before and after the onset of Marcellus Shale activity.

The analysis focused on arrest rates for five crimes: overall minor crimes, driving under the influence, public drunkenness, drug abuse violations, and disorderly conduct. The relationship between Marcellus Shale well development and the arrest rates for each of these crimes was assessed using both descriptive measures and multivariate statistical models that control for factors such as population composition and economic conditions that vary between places and over time. The first set of multivariate models compared crime rates between places – between those with active Marcellus Shale well development and those that had little or no such activity. The second set of models examines change in arrest rates over time – comparing crime prior to Marcellus Shale activity with crime during active Marcellus drilling.

The findings suggest that of the five crimes, driving under the influence and disorderly conduct arrest rates were associated with well density, controlling for other factors. Rates of driving under the influence were higher in counties with high levels of well development compared to counties that did not have well development; however, the counties with high levels of development did not experience

an increase in DUIs from before to during Marcellus well development that was greater than other counties. Counties with higher Marcellus well density had higher rates of disorderly conduct arrest than counties with little or no well activity. Counties with higher well density experienced a larger increase in disorderly conduct arrest rates over time than did counties with lower or no well density. The other three crime categories – minor crimes, public drunkenness, and drug abuse violations – are not significantly related to Marcellus Shale well development across counties or over time.

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The Center for Rural Pennsylvania is a bipartisan, bicameral legislative agency that serves as a resource for rural policy within the Pennsylvania General Assembly. It was created in 1987 under Act 16, the Rural Revitalization Act, to promote and sustain the vitality of Pennsylvania's rural and small communities.

 For more information, contact the Center for Rural Pennsylvania, 625 Forster St., Room 902, Harrisburg, PA 17120, telephone (717) 787-9555, email: info@rural.palegislature.us, www.rural.palegislature.us.

Table of Contents

Executive Summary 1
About this Project 4
Study Counties 4
Marcellus Shale Activity 4
Crime and Natural Resource Extraction 6
Background 7
    Marcellus Shale and Crime Research 8
Data Sources and Descriptions 9
  Marcellus Shale Development Patterns and Data 9
  Crime Data and Sources 11
  County Characteristics as Control Variables 12
Results: Crime Rates by Levels of Marcellus Shale Development 13
Results: Multivariate Analysis of Crime and Marcellus Shale Development 17
  Model 1: Effects of Well Development on Changes in Crime Rates 17
    Change in Minor Crime Arrest Rates 17
    Change in Driving Under the Influence Arrest Rates 17
    Change in Drug Abuse Violation Arrest Rates 18
    Change in Drunkenness Arrest Rates 18
    Change in Disorderly Conduct Arrest Rates 18
  Model 2: Effects of Well Development on Annual Changes in County-level Crime Rates 19
    Minor Crime Arrest Rate 20
    Driving Under the Influence Arrest Rate 20
    Drug Abuse Violations Arrest Rate 21
    Drunkenness Arrest Rate 21
    Disorderly Conduct Arrest Rate 21
Conclusion 23
Report Authors 24
Funding 24
References 25
Appendix A: Control Variables, Data Sources, and Descriptive Statistics 28
Appendix B: Typologies 30
Appendix C: Arrest Rates by County Typologies 31

About this Project

The Marcellus Shale Impacts Project chronicles the effects of shale-based energy development in Pennsylvania by focusing on the experiences of four counties with significant extraction and production activity – Bradford, Lycoming, Greene, and Washington counties. Wave 1 of the project was completed in 2013 and Wave 2 began in early 2014. Wave 1 focused predominantly on data collection and the use of descriptive statistics to present changes in various outcomes over time. Wave 2 focused on developing statistical models to describe relationships between Marcellus Shale development and a set of social and economic indicators, identifying change in social and economic outcomes that are associated with Marcellus Shale development, and identifying the characteristics of people and places associated with the magnitude and types of impact experienced. A particular focus of Wave 2 was to explore the heterogeneity in Marcellus Shale development impact on different population groups. The purpose of this research on changes in arrest rates was to compare these trends in counties with Marcellus drilling activity with those in neighboring counties without that activity and to identify and describe changes in these arrest rates over time concurrent with Marcellus well drilling, and identify heterogeneity in outcomes across different population subgroups.

Study Counties

This study focuses on the same four counties examined in Wave 1 of the Marcellus Shale Impacts Study: Bradford, Lycoming, Greene, and Washington. These counties experienced among the highest levels of Marcellus Shale development in Pennsylvania over the past eight years, and they have diverse populations, histories, economic bases, and geographic locations. These differences allow comparisons that facilitate understanding the potential relationships between Marcellus Shale development and various social, economic, and health outcomes. Regional comparisons are also made based on adjacency to the study counties. The northern tier counties include Bradford, Lycoming, Clinton, Columbia, Montour, Northumberland, Potter, Sullivan, Susquehanna, Tioga, Union, and Wyoming. The southwestern counties include Greene, Washington, Allegheny, Beaver, Fayette, and Westmoreland.

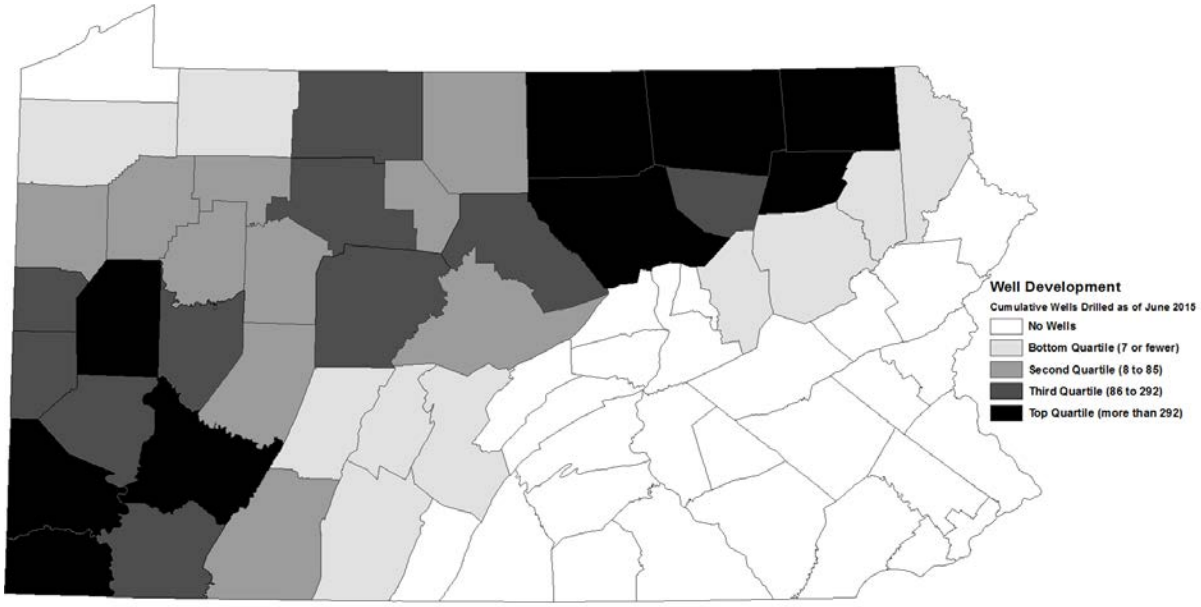
All four study counties are classified as rural by the Center for Rural Pennsylvania with population densities of less than 284 people per square mile. However, USDA's Economic Research Service classifies Lycoming and Washington counties as being located inside metropolitan areas. Lycoming County encompasses much of the Williamsport metropolitan area, and Washington County is part of the Pittsburgh metropolitan area. Bradford and Greene counties are classified by the USDA ERS as being located outside if metropolitan areas. Bradford and Greene counties have small urban populations of less than 20,000 people. However, both are adjacent to metropolitan areas.

Marcellus Shale Activity

Figure 1 presents the distribution of the cumulative number of wells drilled in each county in Pennsylvania through 2015 based on data made available by the Pennsylvania Department of Environmental Protection. To create Figure 1, counties were classified by the number of wells. The first

category is counties with 0 wells; the remaining four categories each represent one-fourth of the remaining counties, or quartiles.

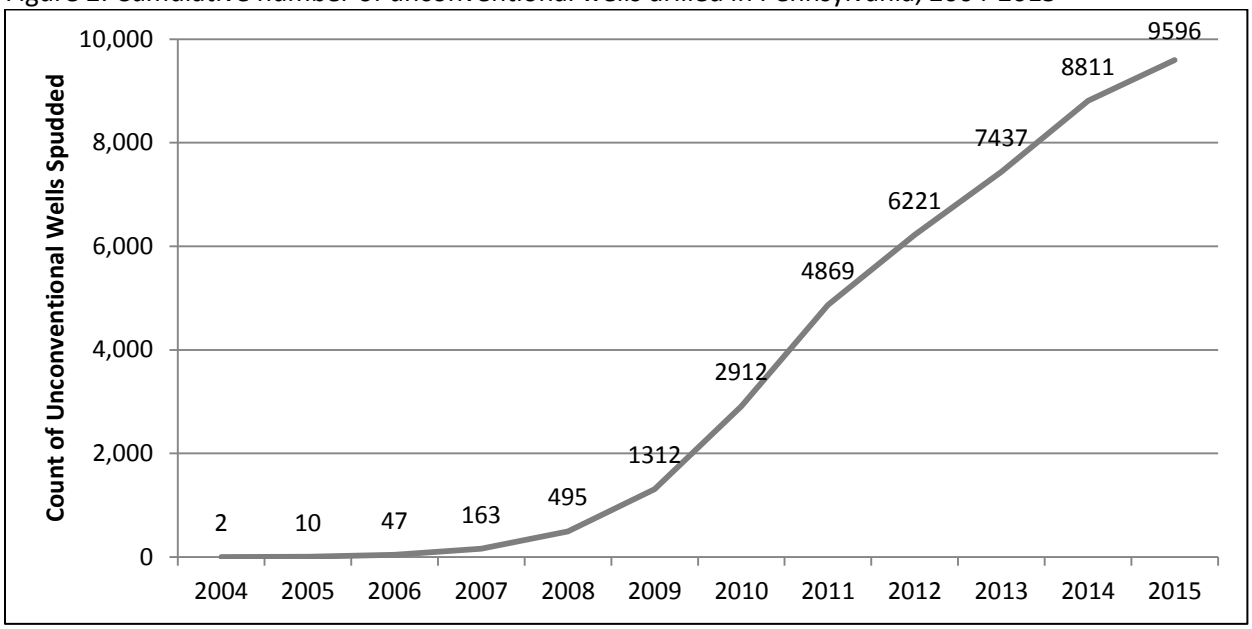
Figure 1. Distribution by County of the Cumulative Number of Unconventional Gas Wells Drilled, 2005 to 2015



Source: PA Dept. of Environmental Protection, Office of Oil and Gas Management

Well development is concentrated in the northeast, northcentral, and southwestern portions of the state. In the northern tier, Bradford, Lycoming, Tioga, Wyoming, and Susquehanna counties have all experienced similar high levels of well development. The southwestern counties with the highest levels of development include Greene, Washington, Westmoreland, and Butler. The complete list of counties in each category is provided in Appendix B.

Figure 2. Cumulative number of unconventional wells drilled in Pennsylvania, 2004-2015



Source: PA Dept. of Environmental Protection, Office of Oil and Gas Management
http://www.depreportingservices.state.pa.us/ReportServer/Pages/ReportViewer.aspx?/Oil_Gas/OG_Well_Inventory

Figure 2 provides a count of the cumulative number of unconventional gas wells drilled in Pennsylvania through 2015. The number of new wells spudded grew from two in 2004 to a height of 1,957 in 2011, before declining in subsequent years. In total, 9,596 unconventional wells were spudded through the end of 2015.

Crime and Natural Resource Extraction

Rapid natural resource development has been linked to increased crime for a number of reasons, including overall population growth, changes to the demographic composition of the population, changes to the social relationships among community members, and increased reporting of crime due to residents' heightened awareness of potential criminal activity and the changing local population. The studies testing these relationships, however, have mixed results, with some finding a relationship (e.g., Freudenburg and Jones, 1991) and others finding none (e.g., Wilkinson et al. 1984). To date, however, only a few have examined this relationship in the Marcellus Shale region, and none have done so using multivariate statistical models to account for other conditions that could affect crime rates.

This research used publicly available data to examine the effects of Marcellus shale development in crime through two analyses. First, the research compared changes in crime from time periods prior to development and during development for all counties to see if counties with wells had a greater change in crime than those without development. Second, arrest rates in counties with and without Marcellus activity across multiple years were examined to see if counties with active well development had different levels of crime from those without development.

Background

Prior studies that sought to understand the impacts of rapid energy development tended to center around changes in the economy, infrastructure and social relations. At the individual level, residents from communities experiencing energy extraction expressed concern over community changes, manifested in decreased senses of security and changes in community identity and well-being (Davidson, 1979; Freudenburg, 1982). Other research has examined stress on individuals and families that may result in child abuse, domestic abuse, mental health problems, and substance abuse, though the findings have been mixed (Wilkinson et al. 1982). Several studies indicated that these concerns vary by the stage of development. Brown et al. (1989) found that concerns about social disruption were highest during the early stages of the energy development, when residents were anticipating potential changes. These early stages of development in the Marcellus Shale – when leasing was occurring and some wells were being drilled but extensive activity was not yet occurring – could have been as early as 2007-2008 in Washington and Greene Counties, about 2008-2009 in Bradford County, and 2009-2010 in Lycoming County.

A series of studies on what were dubbed "boomtowns" – rural, isolated communities largely in the Inter-Mountain West region of the U.S. that experienced rapid development of coal, uranium, and minerals in the 1980s – laid the groundwork for current studies of community impacts of unconventional energy development. Those boomtown studies that examined changes in crime showed mixed findings. Covey and Menard (1983) compared counties with natural resources extraction in Colorado to those without from 1970 to 1979 and found that those with extraction experienced increased arrests for Part I offenses (serious crimes, including criminal homicide, forcible rape, robbery, aggravated assault, burglary, larceny-theft, motor vehicle theft, and arson) as compared to counties without development. However, other studies reported no association (Brookshire and D'Arge, 1980; Wilkinson et al., 1984) between crime and extractive activities, and raised significant questions about the research methods used in these studies, particularly the lack of longitudinal analysis (Wilkinson et al., 1982).

More recent findings on the relationship between natural resource extraction and crime can be drawn from "new boomtown" work in multiple regions of the country. In Sublette County, Wyoming, Jacquet (2005) found that total arrests increased at a rate greater than population growth, and were highly correlated with the number of drilling rigs present in the county. Jacquet found that the largest growth is in uncategorized crime (largely the result of executing outstanding warrants), driving under the influence (DUI), simple assault, drunkenness, and drug possession (Jacquet 2005, p. 4).

In the Bakken Shale region of North Dakota, research indicated that the increase in population associated with development strains police services, which do not gain additional personnel apace with the population growth (Archbold, 2014). Archbold (2014) also found through interviews with 101 police officers in western North Dakota that 96 percent of the officers stated that there was a dramatic increase in calls for service. Additionally, 51 percent of officers mentioned a heightened pressure to move quickly from call to call in a timely manner and 18 percent of officers stated that less important calls for service are sometimes ignored entirely. Also in the Bakken Shale, Ruddel (2014) examined crime

rates for all counties in North Dakota and Montana, finding that violent crimes and property crimes were significantly associated with extraction activity.

Both the historical and current research set the stage for understanding the relationship between crime and natural resource development in the Marcellus Shale region, and provide important lessons about methodologies appropriate for conducting this research. One critical issue is the need for longitudinal analyses to effectively understand the impacts of boomtown development over time, particularly comparing places before and during development (Wilkinson et al., 1982). Second, it is critical to compare places with varying levels of development and places with and without development to understand changes in crime net of other, broader social patterns. As stated by Wilkinson and colleagues in their 1982 comprehensive review of research, "flaws in scholarship are apparent in [the] literature in citations of undocumented assertions as evidence, questionable interpretations of empirical data, overgeneralization of conclusions, and absence of controls in measures of relationships" (Wilkinson et al., 1982, p. 278). Further, upward trends in criminal activity linked to energy development need to be understood within the context of the meaning of crime in rural areas and in relation to heightened awareness of community change (Coleman and Moynihan, 1996). Increases in crime rates may reflect as much increased reporting due to greater vigilance and changed meanings associated with criminal activity as it is to criminal activity brought in by the energy workers. They may also be related to changing patterns of enforcement and police response, as noted by Archbold (2014).

Marcellus Shale and Crime Research

Only a few studies have specifically looked at crime in relation to Marcellus Shale development. In a preliminary study, Kowalski and Zajac (2012) examined calls-for-service by the Pennsylvania State Police (which provides primary coverage in most rural areas of Pennsylvania) and arrests in seven Pennsylvania counties with significant drilling activity for a 5-year period (2006-2010). Their findings indicated no discernible trends in either calls for service or arrests associated with well development. The Multi-State Shale Research Collaborative (2014) conducted a comparative study of Pennsylvania, Ohio, and West Virginia, and found increased serious crime crimes (particularly aggravated assault and larceny-theft) and property crimes and increased pressure on law enforcement agencies in areas with shale development.

Brasier and Rhubart (2014) provided descriptive statistics for calls-for-service, crime reports, arrests, traffic violations, criminal and civil court cases filed, sentencing, and county jail populations for four study counties, for adjacent counties, and for all counties in Pennsylvania. They found increases in several indicators of crime (calls-for-service, driving under the influence, criminal case filings, and traffic violations) in response to increases in wells drilled in some study counties as well as when comparing across all counties by number of wells drilled. However, the authors argued that these associations need to be tested further using statistical methods to control for pre-existing differences across the counties, for changes over time, and for broader population and economic changes experienced in the region. The current report provides these statistical analyses, specifically reporting results from two statistical models:

- The first model (an ordinary least-squares regression model) tests the effects of well development on extent of change (if any) in crime before and after the onset of well development. By examining change between two time periods, this model examines the extent to which well development can be associated with increases or decreases in crime over all study counties.
- The second model (a fixed effects regression model) tests the extent to which well development predicts differences between counties with and without well development over multiple years. By examining trends for the same county over time, the model looks for larger-than-expected deviations in the annual changes that can then be tested for any association with corresponding year-to-year changes in well development.

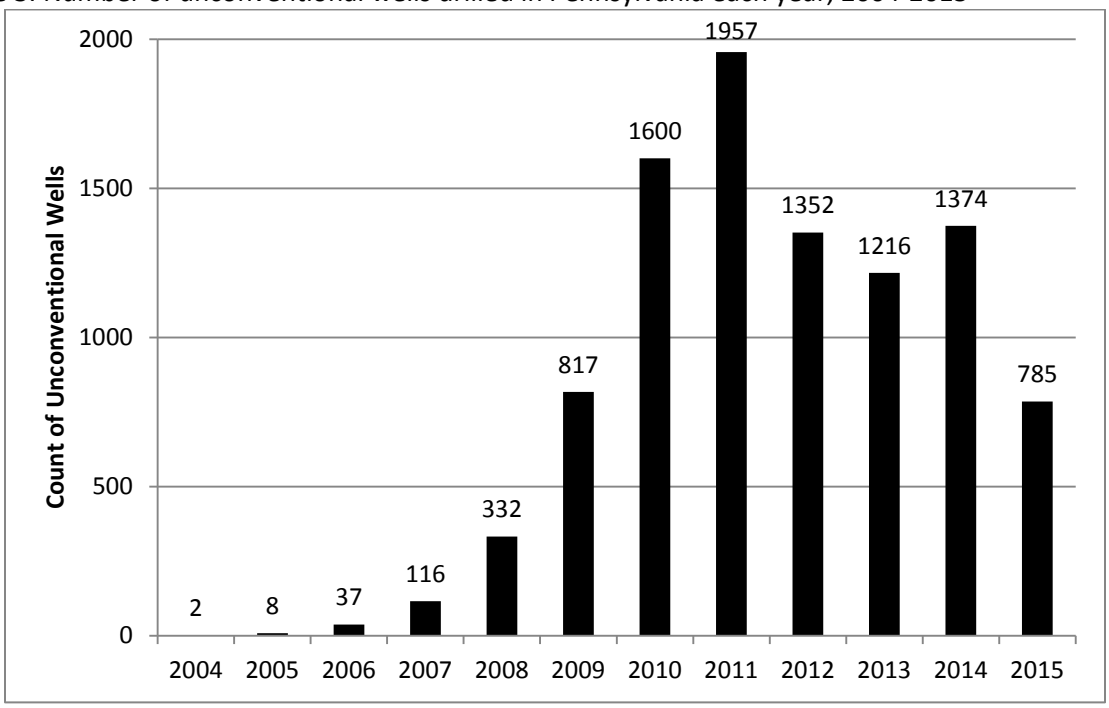
Both models incorporate control variables to account for other potential correlates of changes in crime and for pre-existing demographic characteristics and crime levels.

Data Sources and Descriptions

Marcellus Shale Development Patterns and Data

The rate of development of the Marcellus Shale has resembled that of other types of traditional models of boomtowns and natural resource development. Rate of growth in the number of unconventional wells that were drilled in the Marcellus Shale region of Pennsylvania increased quickly over time. Figure 3 shows the number of wells drilled in Pennsylvania from 2004 through 2015. These numbers are annual counts and are not cumulative.

Figure 3. Number of unconventional wells drilled in Pennsylvania each year, 2004-2015



Source: PA Dept. of Environmental Protection, Office of Oil and Gas Management
http://www.depreportingservices.state.pa.us/ReportServer/Pages/ReportViewer.aspx?/Oil_Gas/OG_Well_Inventory

Annual figures for numbers of unconventional wells drilled were used in the analyses reported below as the measure of Marcellus Shale development activity. While the act of drilling an unconventional well cannot directly cause a change in crime, the number of wells drilled can act as a proxy for the level of shale development in a county. This is based on the presumption that extraction-related population growth (and attendant changes to crime) is highest at the stage of drilling and fracturing a well when the workforce associated with that well is the largest (Brundage et al., 2011). The data for the wells drilled variable were obtained from the Pennsylvania Department of Environmental Protection (DEP) Oil and Gas Well Inventory database on DEP's website (DEP 2015) and were aggregated by county and by year.

The first set of models reported below use measures of well density, calculated as the cumulative number of wells (2004-2012) per 100 square miles, to account for differences in county size. Because this variable is highly skewed (meaning that there are many counties with 0 or a low number of wells and few counties with a high number of wells, which would create bias within the multivariate models), counties are differentiated in the models using three categories: 0 wells per 100 square miles (n=27 counties), between 0.01 and 0.80 wells per 100 square miles (n=19 counties), and greater than 0.80 wells per 100 square miles (n=20 counties). The cut-point of 0.80 represents the mid-point of the distribution of well density (e.g., half of the counties are above it, half below it) for counties that have had at least one well. Appendix B lists the counties in each category.

The second set of models reported below use annual measures of well density, calculated as the total number of wells drilled per square 100 miles in each given year. This variable is also highly skewed, and is therefore differentiated in the models using the same category distinctions listed above.

Crime Data and Sources

The crime variables used in this research were the rates of arrests for five types of crimes aggregated to the county level. The arrest data were obtained from the Federal Bureau of Investigation's (FBI) Uniform Crime Reporting (UCR) system (Department of Justice, 2000-2012). The UCR staff aggregate data submitted from states and individual law enforcement agencies. In Pennsylvania, the State Police collect arrest data from all law enforcement agencies in the commonwealth and classify arrests based on standardized definitions of crimes, then report these data to the FBI (Department of Justice, 2013). The standardization allows for comparisons across states (where laws may differ) and for aggregation from individual agencies to counties and other units.[1] An important limitation is that arrest figures represent crimes for which a report was made, police have investigated, and an alleged perpetrator has been identified (Black, 1970). Arrests also do not reflect crimes committed nor crime victimization as not all crimes are reported.[2] Despite these limitations, arrest data provide a measure of crime that is consistent across places, available annually, and aggregated at the county level to match with other data to be used in the models (including well data).

Annual data on arrests were collected for the years 2005-2012[3] from the Inter-University Consortium for Political and Social Research web-based data archive.[4] The first measure is an aggregate count of all minor crimes (Part II crimes) including: non-aggravated assaults, forgery, fraud, embezzlement, buying/receiving/possessing stolen property, vandalism, weapons violations, prostitution and commercial vice, sex offenses, gambling, offenses against families and children, liquor law violations, drunkenness, disorderly conduct, vagrancy, suspicion, drug abuse violations (including possession and sales), and all other offenses.[5] Then four individual crimes were examined that were specifically identified in recent studies to be affected by rapid development of natural resources in other

[1] The standardized categories were derived by the FBI to be consistent with the National Crime Information Center classification of offenses. For further detail about the classifications, see the National Incident-Based Reporting System User Manual (Department of Justice, 2013).

[2] In addition to arrests, two other indicators of crime are frequently used to describe criminal activity in the United States (Department of Justice, 2009). The first, reports of crime, are also collected by law enforcement and made available through the Federal Bureau of Investigation Uniform Crime Reporting system. Crime reports are only compiled for the most serious offenses (murder and non-negligent manslaughter, forcible rape, robbery, aggravated assault, burglary, larceny-theft, motor vehicle theft, and arson), whereas arrest data are available for an additional 21 crimes. The second, reports of crime victimization, are based on the National Crime Victimization Survey conducted twice annually with representative samples of the general population. These data are not available at the county level (see Fay and Diallo, 2015 for state-level estimates).

[3] At the time the data were downloaded (January, 2015), this was the last year of complete data available from the Inter-University Consortium for Political and Social Research.

[4] Although one study did find a relationship between serious crime (primarily aggravated assault and larceny theft) and unconventional shale development (Multi-State Shale Research Collaborative, 2014), previous research using the same data included here found little change in serious crimes in the Marcellus shale region (Brasier and Rhubart, 2014). Consequently, these measures (murder, manslaughter, rape, robbery, aggravated assault, burglary, larceny-theft, motor vehicle theft, and arson) were not considered here.

[5] These include violations of local and state laws (not traffic laws) not otherwise categorized (see https://www2.fbi.gov/ucr/cius_04/appendices/appendix_02.html).

unconventional oil and gas development (Jacquet, 2005; Parkins and Angell, 2011) and for which Brasier and Rhubart (2014; see also Multi-State Shale Research Collaborative, 2014) found potential associations with levels of Marcellus Shale development:

- Driving under the influence (DUI): "Driving or operating a motor vehicle or common carrier while mentally or physically impaired as the result of consuming an alcoholic beverage or using a drug or narcotic."
- Drunkenness: "To drink alcoholic beverages to the extent that one's mental faculties and physical coordination are substantially impaired. Excludes driving under the influence."
- Drug abuse violations: "The violation of laws prohibiting the production, distribution, and/or use of certain controlled substances. The unlawful cultivation, manufacture, distribution, sale, purchase, use, possession, transportation, or importation of any controlled drug or narcotic substance. Arrests for violations of state and local laws, specifically those relating to the unlawful possession, sale, use, growing, manufacturing, and making of narcotic drugs. The following drug categories are specified: opium or cocaine and their derivatives (morphine, heroin, codeine); marijuana; synthetic narcotics —manufactured narcotics that can cause true addiction (demerol, methadone); and dangerous nonnarcotic drugs (barbiturates, benzedrine)."
- Disorderly conduct: "Any behavior that tends to disturb the public peace or decorum, scandalize the community, or shock the public sense of morality."[6]

To account for population size differences across counties, rates are calculated as arrests per 100,000 residents in that year.

County Characteristics as Control Variables

The multivariate models included several variables to control for factors that are known to influence crime rates. Doing so isolates the influence of the main variable of interest, well density. These control variables included:

- Population density (persons per square mile)
- Percent of the population that is male and 18-34 years of age
- Percent of the civilian population age 16 and over (i.e. the labor force) that is unemployed
- Percent of the population[7] living in poverty[8]
- Percent of the labor force employed in construction, extraction, or maintenance
- Percent of the labor force employed in production and transportation

[6] These definitions are taken from the FBI website: (https://www2.fbi.gov/ucr/cius_04/appendices/appendix_02.html).
[7] Poverty status under the ACS is determined for all people excluding those who are institutionalized, in military group quarters, in college dormitories, and unrelated individuals under the age of 15 years old.
[8] The census determines poverty status based on whether the family has cash-based income (excluding the family's property or financial assets) below a specified threshold for the family's size. To see the thresholds for a given year, see: http://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html.

Because annual county level data are not available for all study counties due to low population sizes, 5-year estimates (2005/09 and 2009/13) were obtained from the Census Bureau's American Community Survey (ACS) via the Social Explorer website (Social Explorer, 2015). For each control variable of interest in the percent change models (Table 2), two values were included: the 2005/09 estimates and the percentage change between the 2005/09 and 2009/13 estimates. Including both variables incorporated both baseline conditions and change concurrent with the study period. In the fixed-effects models (Table 3), only the baseline was included. Descriptive statistics for these variables can be found in Appendix A.

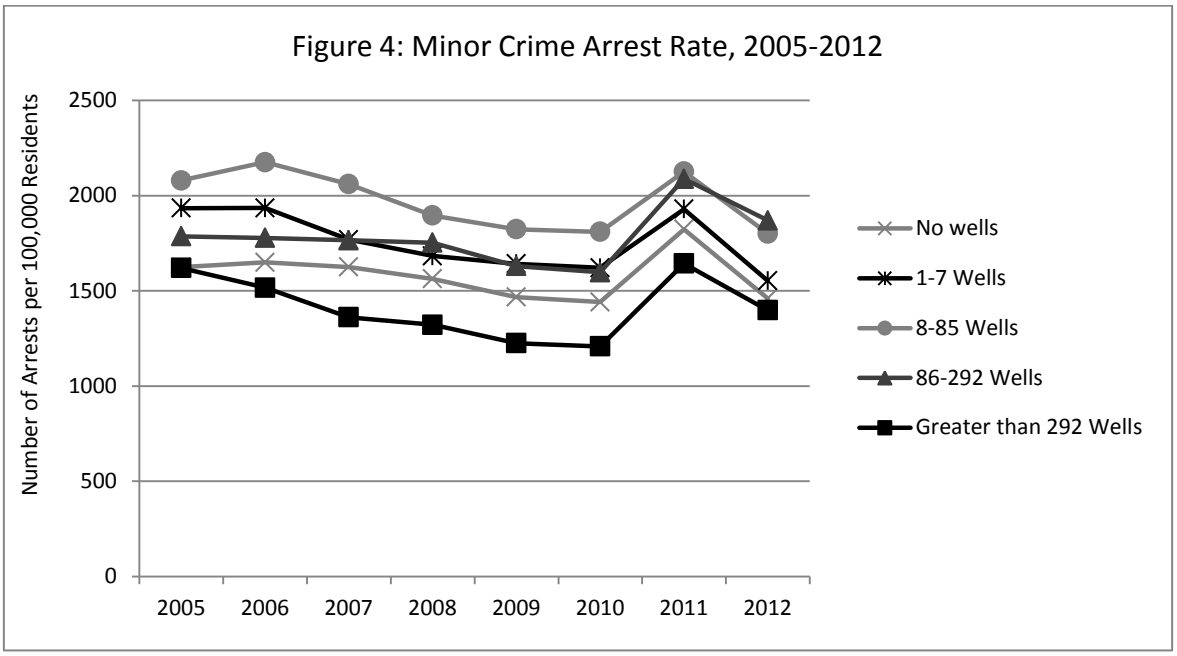
One important point to note is that because of the methods by which the ACS is conducted, it is unlikely to include temporary (e.g., those living in hotels/motels) workers living in these counties. This means that there was likely to be an undercount of the temporary shale-related population in the county. The shale-related population change that is more permanent (living in homes and rental units) would be counted in the ACS. Therefore the ACS control variables are primarily related to more permanent population change in each county. The degree to which the Marcellus-related workforce is temporary or permanent may vary by county, based on the distribution of oil and gas firms/offices and pre-existing housing availability (Williamson and Kolb, 2011). Because of the standardization of arrest counts by the permanent, resident population, changes in arrest rates might be artificially high because the (uncounted) temporary workers are not included in the population change figures used in the denominator to calculate the arrest rates during periods of high drilling activity.

Results: Crime Rates by Levels of Marcellus Shale Development

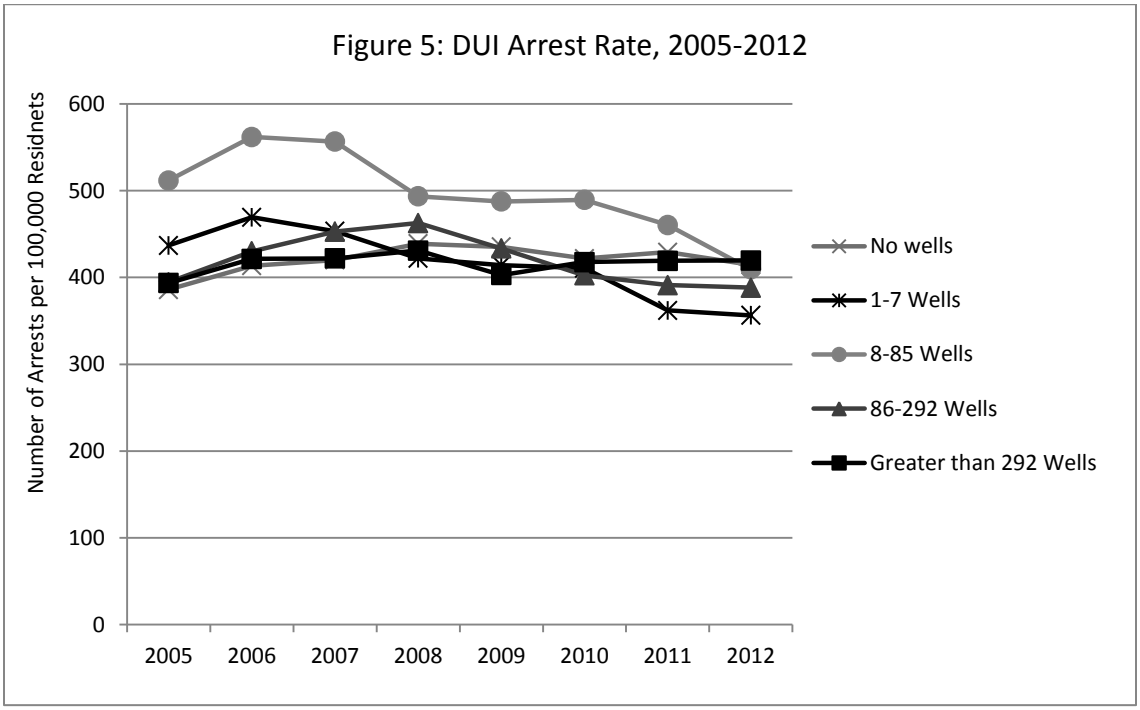
The crime data examined here include 66 of 67 Pennsylvania counties (Philadelphia County was excluded).[9] Figures 4 through 8 present the mean (average) arrest rates for each type of crime using a typology that indicates level of Marcellus Shale development (see Figure 1 for additional detail on the typology). Appendix C includes the full data table from which these figures were derived.

Figure 4 indicates the average county arrest rates for minor crimes from 2005 through 2012 across county type. In all county types, the trend from 2005 through 2010 was a decline in the average, with a sharp increase in 2011 for all categories of counties followed by a decrease again in 2012. It is unclear to what the 2011 increase may be attributed, especially given that all counties experienced similar changes. Counties in the highest well count category (more than 292 wells) had the lowest average minor crime rates in all years.

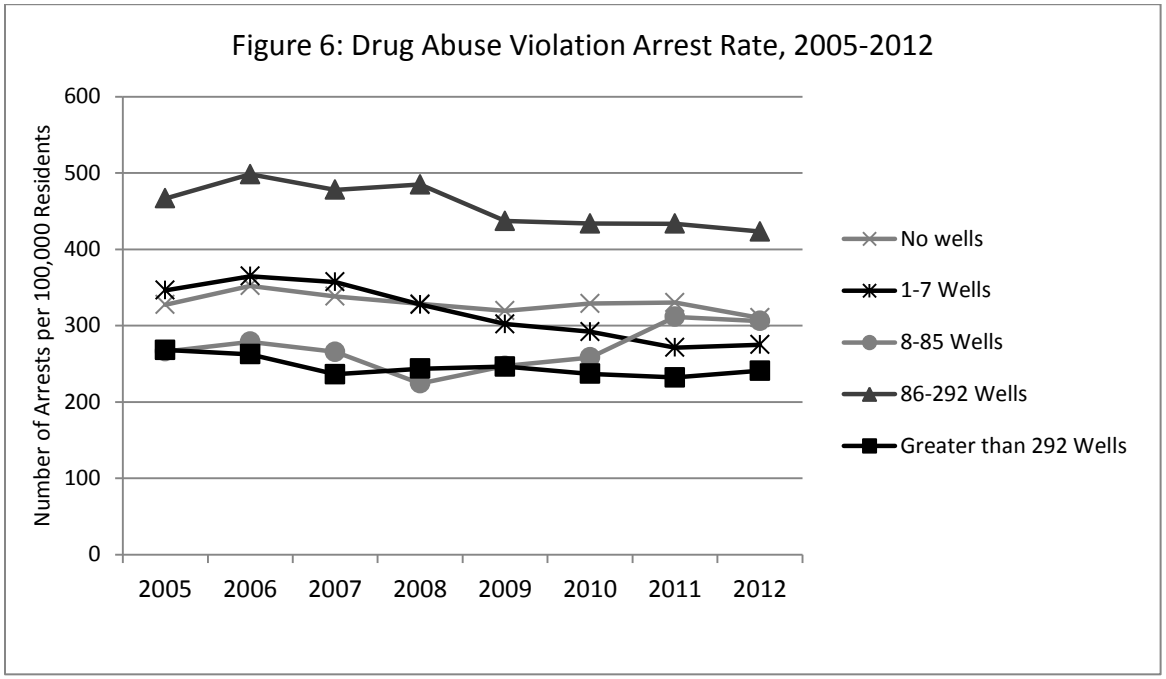
[9] Philadelphia County was excluded from the analyses as it varied substantially from other non-Marcellus counties along several of the demographic (population density, poverty, median income) and all five crime variables.



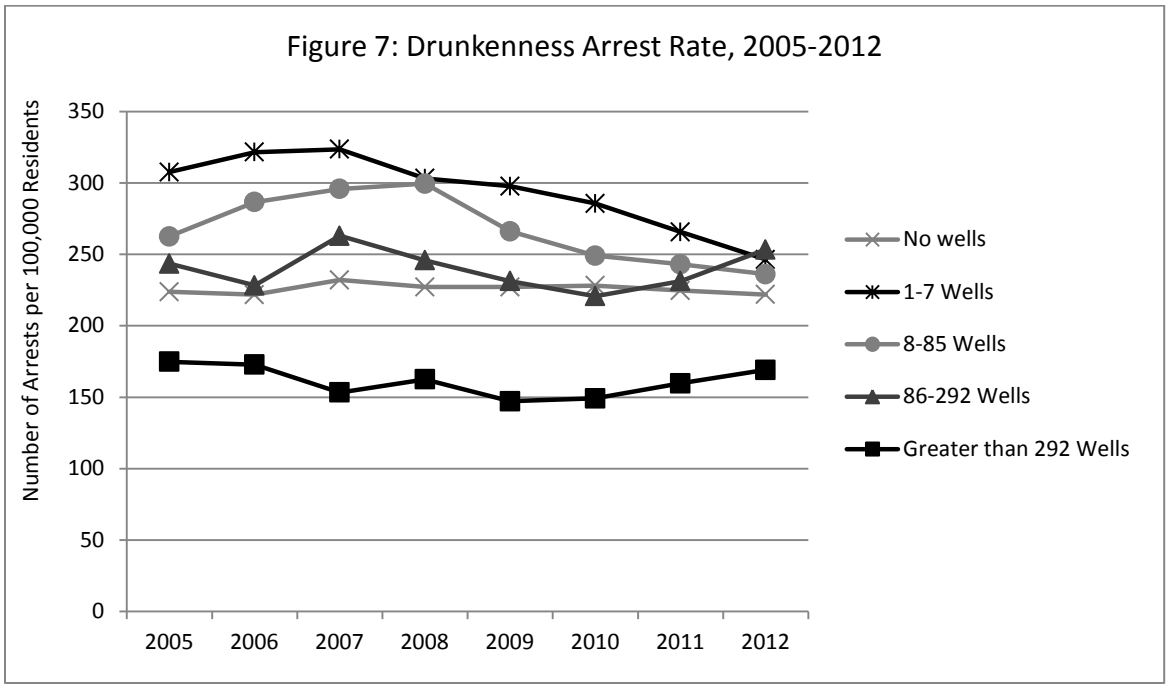
The average arrest rates for driving under the influence (DUI) (Figure 5) increased for all categories of the typology from 2005 to 2006. Following 2006, two trends tended to occur. For counties with no wells and those with more than 292 wells, the trend varied slightly from year to year, but stayed relatively consistent. The average DUI arrest rates for the three middle categories of well counts declined over time following 2006. Interestingly, the mean DUI arrest rate for counties with 8-85 wells started higher than all other categories, but, by 2012, they declined and converged with other categories.



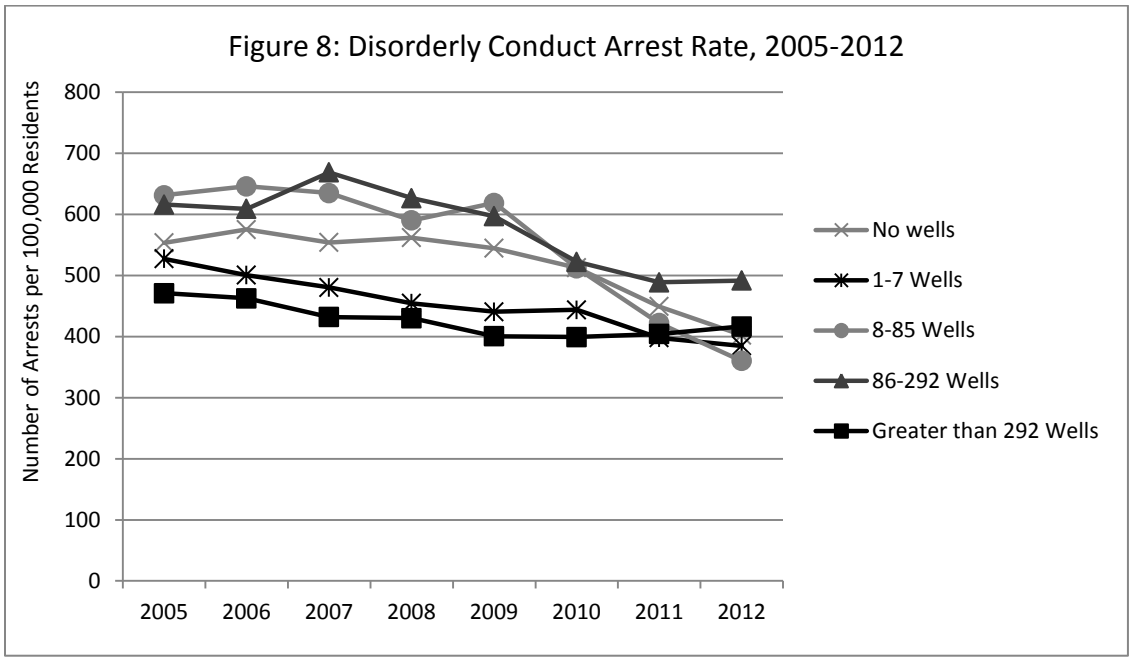
Trends for drug abuse violation arrest rates (Figure 6) for counties with 8-85 wells increased markedly from 2008 to 2012. In comparison, all other categories witnessed overall declines in rates of drug abuse violation arrests from 2005 to 2012. This decrease was smallest in counties with no wells and counties with more than 292 wells. While drug abuse arrests in counties with 86-292 wells decreased over time, this category maintained the highest rates of drug abuse violation arrests across all years.



The drunkenness arrest rate (Figure 7) trends indicated that the mean for counties with more than 292 wells decreased from 2005 through 2007 and began increasing after 2010. The mean rate for counties with 86-292 wells experienced an uptick in 2007, which gradually declined until 2010, when it began to increase again. Drunkenness arrest rates in counties with 8-85 wells and 1-7 wells increased in the first few years, but then decreased in the later years. The average for counties with no wells remained rather consistent from 2005 through 2012.



In general, the trends for disorderly conduct arrests (Figure 8) for all county types declined over the study period. The two differences were for counties with more than 292 wells, which plateaued in 2009 and 2010 and then began to increase. Counties with 8-85 wells and 86-292 wells declined overall during this time period, but started with the highest means in 2005, experienced small upticks in the earlier years of drilling, and then declined and began converging with the other categories of the typology.



The results of the bivariate descriptive graphs provide a mixed picture. While the mean arrest rate for counties with more than 292 wells did not appear to increase markedly for any type of crime, in many cases (e.g. DUI, drug abuse violations, disorderly conduct, and public drunkenness) the mean for these counties stayed rather consistent while other categories of the typology experienced general declines over time. This is consistent with other preliminary research (Kowalski and Zajac, 2012).

Results: Multivariate Analysis of Crime and Marcellus Shale Development

The descriptive results shown above suggest the need for more examination of the relationships between criminal activity and well development. In this section, the relationships are examined further using multivariate statistical models, which control for (take out) the effects of differences across places and over time. Doing so isolates the effects of well development, allowing for the assessment of the strength and direction of this relationship. Two models were used to assess this relationship.

Model 1: Effects of Well Development on Changes in Crime Rates

The first set of models (an ordinary least-squares regression model) test the effects of well development on extent of change (if any) in crime before and after the onset of well development. Table 2 presents statistical models that examine the effects of well density on the percentage change in the rates between 2007 and 2012. These models help to identify whether counties with more wells have a greater increase or decrease in arrest rates from 2007 to 2012 than counties with fewer or no wells, controlling for county-level demographic and socioeconomic factors known to affect changes in arrest rates. This provides another way of examining the effects of natural gas development on crime rates during the time when drilling was most active. Table 2 provides the results for the models of changes in arrest rates between 2007 and 2012 for the five types of crimes.

Change in Minor Crime Arrest Rates

Well density had no statistically significant relationship with change in minor crime arrest rates between 2007 and 2012. Counties with wells did not experience statistically different changes in minor crime arrest rates than counties without wells. Only two starting conditions (the arrest rates in 2007 and percent poverty in 2005/9) were statistically related to the change in minor crime arrest rates. Counties with lower arrest rates in 2007 had larger increases in minor crime arrest rates between 2007 and 2012; those with higher rates of poverty in 2005/9 had larger increases in minor crime arrest rates between 2007 and 2012.

Change in Driving Under the Influence Arrest Rates

Similarly, well density had no statistically significant relationship with change in DUI arrest rates between 2007 and 2012. Only the arrest rates in 2007 were significant, indicating that counties with higher arrest rates in 2007 had large increases in arrest rates between 2007 and 2012.

Change in Drug Abuse Violation Arrest Rates

Well density was not a statistically significant predictor of changes in drug abuse violation arrest rates. Counties with well development experienced percentage changes in drug abuse violation arrest rates that were not statistically significantly different from counties without well development. Similar to minor crime arrest rates, only the arrest rates in 2007 and percent poverty in 2005/9 were statistically related to the change in drug abuse violation arrest rates. Counties with higher arrest rates in 2007 had larger increases in drug abuse violation arrest rates; those with higher rates of poverty in 2005/9 had larger increases in drug abuse violation arrest rates.

Change in Drunkenness Arrest Rates

Counties with wells did not experience significantly different percentage changes in drunkenness arrest rates than counties without wells between 2007 and 2012. As in other models, counties with lower arrest rates in 2007 had larger increases in the arrest rate between 2007 and 2012.[10]

Change in Disorderly Conduct Arrest Rates

The one exception was for percent change in disorderly conduct arrest rates; counties with the highest density of wells had a marginally significant (less than 10 percent likelihood that it is by chance) larger percentage increase in arrest rates between 2007 and 2012 than counties with no wells. As in other models, counties with lower disorderly conduct arrest rates in 2007, larger percentages of families in poverty, and greater increases in the percentage of families in poverty between 2005/9 and 2009/12 had larger increases in disorderly conduct arrest rates between 2007 and 2012.

[10] It also should be noted that the model itself for drunkenness is not significant, meaning that the combination of variables examined in the model performed poorly in predicting change in drunkenness arrests.

Table 2: Ordinary Least Squares Regression Results of Well Density on Percentage Change in Arrest Rates in Pennsylvania Counties, 2007-2012 (n=66)

	Percent Change in Minor Crime Arrest Rate	Percent Change in DUI Arrest Rate[a]	Percent Change in Drug Abuse Violation Arrest Rate[a]	Percent Change in Drunkenness Arrest Rate	Percent Change in Disorderly Conduct Arrest Rate
Variable	**Est. (St. Error)**	**Est. (St. Error)**	**Est. (St. Error)**	**Est. (St. Error)**	**Est. (St. Error)**
Intercept	22.97	149.04***	181.57***	16.32	4.21
	(18.25)	(0.32)	(0.43)	(29.41)	(22.87)
Well Density (ref=0) *(0 wells/100 sq mi (n=27)*					
Lower 50th Percentile (*0.01 – 0.80 wells/100 sq mi (n=19)*)	-7.28	0.89	0.84	-4.58	-3.21
	(6.17)	(0.11)	(0.14)	(9.95)	(7.93)
Upper 50th Percentile (*0.80 or more wells/100 sq mi (n=20)*)	2.17	1.13	1.02	3.31	**14.97^**
	(6.19)	(0.11)	(0.14)	(10.10)	(7.85)
Arrest Rate 2007	**-0.03*** **	**1.00*** **	**1.00** **	**-0.13** **	**-0.12*** **
	(0.01)	(0.00)	(0.00)	(0.05)	(0.02)
Population Density, 2005/09	0.00	1.00	1.00	0.01	0.01
	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
% Change in Pop. Density	0.05	1.01	1.00	-0.51	-0.73
	(1.07)	(0.02)	(0.02)	(1.81)	(1.37)
Percent Male 18-34, 2005/09	-0.28	0.99	0.94*	0.40	-1.66
	(1.23)	(0.02)	(0.03)	(1.97)	(1.55)
% Change in Pop. Male 18-34	0.78	1.00	1.04	-0.22	0.11
	(0.61)	(0.01)	(0.01)	(0.96)	(0.76)
Percent Poverty, 2005/09	**2.61***	1.02	**1.04** **	0.99	**3.41***
	(1.18)	(0.02)	(0.03)	(2.049)	(1.45)
% Change in Percent Poverty	0.29	1.00	1.00	0.34	**1.20*** **
	(0.23)	(0.00)	(0.01)	(0.38)	(0.31)
Percent Emp. in Construction, Extraction & Maint., 2005/09	-1.28	1.01	0.98	-1.96	-1.08
	(1.07)	(0.02)	(0.03)	(1.94)	(1.36)
% Change in Percent Emp. In Construction, Extraction & Maint.	-0.11	0.99	0.99	-0.50	-0.11
	(0.23)	(0.00)	(0.00)	(0.40)	(0.30)
F-statistic	**	***	**		***
R-squared	0.38	0.43	0.39	0.21	0.49
Adj. R-squared	0.26	0.31	0.26	0.05	0.39

[a] The DUI and drug abuse violation arrest rate residuals were not normally distributed, and therefore the variables were logged to meet this assumption. The coefficients presented in the table have been exponentiated for interpretation purposes.

*** p<.001, **=p<.01, *=p<.05, ^=p<.10

Model 2: Effects of Well Development on Annual Changes in County-level Crime Rates

The first model assessed the effects of shale development, as measured by well density (wells/100 square miles), on each county's crime rates over the period of 2005-2012. The model, which is called a pooled time-series model with county and year fixed effects, examined the levels of crimes for each

county and assesses whether, and to what extent, these levels are associated with shale development.[11] The advantage of fixed effects models is that, because the model looks at rates in each county for multiple points in time, the characteristics of the counties themselves are "fixed" – because counties' social and economic conditions do not change dramatically over time, individual county characteristics as explanations for differences in explaining crime levels are removed (Allison, 2005; Amato and Beattie, 2011; Firebaugh, 2008). Fixed effects models ignore between-county variation because they focus explicitly on in-county variation over time in relation to concurrent levels of well development.[12]

The effect of time can be examined in the model by examining the extent of changes in crime rates annually in comparison to the base year of 2005. This provides the ability to identify whether specific years (particularly those during heightened well development) were associated with changes in arrest rates. Finally, the model includes variables to control for other characteristics that are known to affect crime rates.

Minor Crime Arrest Rate

Table 3 reports the results for minor crime arrest rates in the second column. The results show that counties with the highest well density (greater than 0.80 wells/100 mi^2) have lower minor crime rates than counties with no wells, though this is only marginally significant (probability less than 10 percent). Counties with lower well densities (.01-.80 wells/100 mi^2) did not have statistically different crime rates than counties with no wells. The models also indicated that, holding 2005 as the base year and controlling for all other variables in the model, minor crime arrest rates were significantly lower in 2008, 2009, 2010, and 2012, the most active years of natural gas development. Both of these findings – lower rates in counties with the highest numbers of wells and during years of active well development – are consistent with the trends identified in Figure 4 above. The strongest predictors (the variables with significant coefficients at the .05 level or below and largest coefficients) are demographic and economic variables: counties that experienced increasing crime rates over the study period (2005-2012) had, in the beginning of the study period, higher proportions of young men (ages 15-39), higher proportions of people in poverty, and lower proportions of people employed in construction, extraction, and maintenance.

Driving Under the Influence Arrest Rate

Table 3 provides results for driving under the influence (DUI) arrest rates in the third column. Well density was significantly related to DUI arrest rates; counties with wells (at either density level) had significantly more DUIs per 100,000 residents than counties with 0 wells. The model also indicated that 2006, 2007, 2008, and 2009 had significantly higher rates of DUI arrests than the base year, 2005. This model suggests that the arrest rates for DUIs were higher among counties with a large density of wells

[11] There are a total of 528 observations in the model, 66 counties for each of 8 years.

[12] Diagnostics were used to test the variables in the model so that model assumptions (normality, heteroskedasticity, and multicollinearity) were not violated. Those variables that were not normally distributed were re-calculated as the log of the original value and are noted in the results tables. Control variables with high covariation (evidence of multicollinearity) were removed.

and very early in the period of active well development (2007-2009) in comparison to the base year, controlling for other community influences.

Drug Abuse Violations Arrest Rate

Well density was not a significant predictor of drug abuse violation arrest rates (Table 3, column 4). Further, the year variables did not indicate significant changes over time in these rates. Other demographic and socioeconomic characteristics (including population density, percentage of young men in the population, poverty, and employment patterns) were significant predictors of drug abuse violation arrest rates.

Drunkenness Arrest Rate

The fifth column of Table 3 provides the results from the model for drunkenness arrest rates. For this crime, the relationship to well density was statistically significant and negative, indicating that counties with the highest well densities experienced a lower rate of arrests for drunkenness compared to counties with no wells. Year was not significant, suggesting that the rate did not change significantly over time. These findings are consistent with the descriptive analysis provided in Figure 7, which indicates that counties with high well development have consistently lower rates of arrests for drunkenness.

Disorderly Conduct Arrest Rate

The final model examined rates of arrests for disorderly conduct (Table 3, column 6) and indicated that counties with more than 0.80 wells/mi^2 have a marginally significant higher arrest rate for disorderly conduct than counties without wells. The year variables indicate statistically significant declines in arrest rates in 2010, 2011 and 2012. Other demographic and socioeconomic characteristics of counties (population density, unemployment, poverty, and employment patterns in the beginning of the time period) were also predictors of disorderly conduct arrest rates. This supports the descriptive analysis above (Figure 8), which indicates that rates were trending downward through this period for most counties.

Table 3: County and Year Fixed Effects Regression Results of Well Density on Arrest Rates in Pennsylvania Counties, 2005-2012 (N=528)

Variable	Minor Crime Arrest Rate Est. (St. Error)	DUI Arrest Rate Est. (St. Error)	Drug Abuse Violation Arrest Rate[A] Est. (St. Error)	Public Drunkenness Arrest Rate Est. (St. Error)	Disorderly Conduct Arrest Rate Est. (St. Error)
Intercept	1132.70***	359.54***	544.57***	219.04***	328.28***
	(158.94)	(50.79)	(0.202)	(36.81)	(64.45)
Well Density (ref=0) *(0 wells/100 sq mi (n=27)*					
Lower 50th Percentile (*0.01 – 0.80 wells/100 sq mi (n=19))*	-29.95	**30.78***	0.98	-10.42	18.68
	(43.18)	(13.95)	(0.06)	(10.10)	(17.81)
Upper 50th Percentile (*0.80 or more wells/100 sq mi (n=20))*	**-76.19^**	**39.38****	0.93	**-31.50****	**13.65^**
	(44.54)	(15.04)	(0.06)	(10.20)	(17.84)
Population Density, 2005/09	0.02	-0.01	**1.00*****	**0.03****	**0.11*****
	(0.04)	(0.01)	(0.00)	(0.01)	(0.02)
Percent Male 18-34, 2005/09	**22.36*****	**7.36*****	**0.97*****	-0.10	-1.18
	(6.56)	(2.12)	(0.01)	(1.52)	(2.67)
Percent Unemployed, 2005/09	-14.19	-5.15	1.00	**13.48*****	**30.98*****
	(15.86)	(5.12)	(0.02)	(3.68)	(6.45)
Percent Poverty, 2005/09	**62.58*****	2.14	**1.03*****	**12.13*****	**6.40***
	(6.90)	(2.22)	(0.01)	(1.61)	(2.82)
Percent Emp. in Construction, Extraction & Maint., 2005/09	**-19.36****	1.879	**0.97****	**-15.62*****	**-11.06*****
	(7.48)	(2.41)	(0.01)	(1.74)	(3.05)
Percent Emp. in Production & Transportation, 2005/09	-2.69	**-2.41^**	**0.97*****	**-5.45*****	0.38
	(3.91)	(1.26)	(0.01)	(0.91)	(1.59)
2005 (reference year)	0.00	0.00	1.00	0.00	0.00
	(.)	(.)	(.)	(.)	(.)
2006	22.12	**33.08^**	1.05	2.01	-3.78
	(63.98)	(18.86)	(0.07)	(14.99)	(26.02)
2007	-59.87	**35.43***	0.96	9.15	-9.16
	(62.41)	(18.18)	(0.07)	(14.58)	(25.34)
2008	**-130.83***	**31.61^**	0.99	4.96	-16.33
	(62.38)	(17.89)	(0.08)	(14.89)	(26.09)
2009	**-205.94*****	**30.97^**	1.00	-1.64	-25.07
	(61.48)	(18.73)	(0.08)	(14.36)	(26.92)
2010	**-240.64*****	29.47	0.99	-2.30	**-67.23****
	(61.12)	(19.48)	(0.07)	(14.31)	(25.28)
2011	77.60	9.65	0.95	-5.29	**-123.46*****
	(66.90)	(20.70)	(0.08)	(14.34)	(24.12)
2012	**-199.11*****	4.76	0.94	-6.88	**-142.28*****
	(61.21)	(21.36)	(0.08)	(13.63)	(23.51)
-2 Res Log Likelihood	7512.1	6356.9	692.4	6018.3	6599.2
AIC (Smaller is Better)	7528.1	6372.9	708.4	6034.3	6615.2
AICC (Smaller is Better)	7528.4	6373.2	708.7	6034.6	6615.5
BIC (Smaller is Better)	7545.6	6390.4	725.9	6051.8	6632.7
Chi Square	6.38	9.51	5.87	7.71	12.57^

[A] The drug abuse violation arrest rate residuals were not normally distributed, and therefore the variable was logged to meet this assumption. The coefficients presented in the table have been exponentiated for interpretation purposes.

*** p<.001, **=p<.01, *=p<.05, ^=p<.10

Conclusion

This research examined the relationship between unconventional well drilling and arrest rates in Pennsylvania counties, specifically examining arrest rates for minor crimes, DUI, drug abuse violations, public drunkenness, and disorderly conduct. Three approaches to understanding the relationships are reported here: bivariate analyses of counties' annual arrest rates by the number of wells drilled, a model that tested the effects of well density on the percent change in arrest rates between 2007 and 2012, and a multivariate model that explored the relationship of well density with annual arrest rates.

The results for **minor crime arrest rates** indicated that counties with the highest number of wells experienced overall decreases in arrest rates over the study time period (2005-2012), as did other counties in the commonwealth. The arrest rates for the counties with the most wells had larger decreases than counties with no wells over this time period; however, the percent change in arrest rates between 2007 and 2012 was no different than counties without wells. For **driving under the influence arrest rates**, counties with a large number of wells had relatively steady DUI arrest rates over the 2005-2012 time period, whereas counties without wells had declining rates over the time period. These descriptive findings are verified by the multivariate model, which indicated a significant statistical relationship between well density and DUI arrest rates. Counties with wells (at both levels) had higher DUI arrest rates than counties without wells throughout the study period. However, counties with wells did not experience statistically significant increases in DUI arrest rates between 2007 and 2012. **Drug abuse violation arrest rates** did not appear to be related to well development; the rates for counties with a high number of wells did not change significantly over the study period as indicated by the bivariate analysis, and the statistical models showed no relationships with the level of arrest rates or the change in arrest rates. The bivariate results for **drunkenness arrest rates** indicated that counties with the highest numbers of wells had lower levels but increasing rates in comparison to other counties from 2010-2012. The statistical models indicated that counties with the highest density of wells had significantly lower arrest rates than other counties, but no significant relationship to changes in arrest rates. Similarly, the bivariate results indicated that **disorderly conduct arrest rates** for counties with a large number of wells held relatively steady during the years that other counties experienced declines. The statistical models support these initial findings, as counties with the highest density of wells had higher arrest rates and had greater increases in arrest rates between 2007 and 2012.

Overall, these findings indicate that counties with substantial well development are experiencing increases in arrest rates associated primarily with driving under the influence and disorderly conduct. It is uncertain how much of the changes in county characteristics are related to Marcellus Shale development, however. Studies from previous research in this project did not indicate substantial changes in population data available from the U.S. Census Bureau, as only those workers moving into more permanent housing would be captured through Census of Population or American Community Survey data collection protocols. The short-term "pulses" associated with temporary workers are difficult to track, as they are limited in both time and space, and their community impacts would also be more episodic and spatially circumscribed. Consequently, there is a mismatch between the county-level

and annual (or multi-year) data available through secondary sources and the nature of the workforce deployment within the oil and gas industry that makes assessing impacts difficult.

Another consideration when interpreting these findings is that arrest rates, used here, are not the same as crime or crime rates. Arrests require some level of law enforcement intervention and investigation; not all crimes result in arrests. While arrest rates can provide an indication of crime, they are also an indication of police activity and areas of enforcement. Law enforcement may increase emphasis on certain crimes (such as DUIs), resulting in more arrests, without an increase in the actual number of crimes. And community change may also increase reporting of crime, influencing arrest rates.

These findings are consistent with those from previous studies of crime in the Marcellus Shale region, showing limited relationships between crime and natural gas extraction. However, the findings are contrary to those in other contemporary shale plays, particularly the Bakken (e.g., Archbold et al., 2014), suggesting that significant differences between shale plays, their host communities, law enforcement practices, and extraction processes may lead to differing outcomes.

Report Authors

Kathryn Brasier, Associate Professor of Rural Sociology
Danielle Rhubart, PhD Student in Rural Sociology and Demography

Other Research Team Members
Kathryn Brasier, PhD – Associate Professor of Rural Sociology
Leland Glenna, PhD – Associate Professor of Rural Sociology
Timothy Kelsey, PhD – Professor of Agricultural Economics
Kai Schafft, PhD – Associate Professor of Educational Leadership & Director of Center on Rural Education and Communities
Shannon M. Monnat, PhD – Assistant Professor of Rural Sociology, Demography, and Sociology
Mark Suchyta – MS Student in Rural Sociology
Joshua Perchinski – MS Student in Rural Sociology
Raeven Faye Chandler – PhD Student in Rural Sociology and Demography
Max Pohlman – Undergraduate Student

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Appendix A: Control Variables, Data Sources, and Descriptive Statistics

Table 4. Variables and Data Sources

Variable	*Year(s)*	*Source*
FIPS	2005-2012	US Census, Social Explorer
Year	2005-2012	US Census, Social Explorer
County	2005-2012	US Census, Social Explorer
Minor Arrests	2005-2012	UCR Data, ICPSR
DUI Arrests	2005-2012	UCR Data, ICPSR
Drug Abuse Violation Arrests	2005-2012	UCR Data, ICPSR
Public Drunkenness Arrests	2005-2012	UCR Data, ICPSR
Disorderly Conduct Arrests	2005-2012	UCR Data, ICPSR
Well Count	2005-2012	PA Department of Environmental Protection
Total Population	2005/09, 2009/13	US Census, Social Explorer
Population Density	2005/09, 2009/13	US Census, Social Explorer
Land Area	2005/09, 2009/13	US Census, Social Explorer
Percent of the population that is male and age 18-34	2005/09, 2009/13	US Census, Social Explorer
Percent of the population that is in poverty	2005/09, 2009/13	US Census, Social Explorer
Percent of the labor force that is unemployed	2005/09, 2009/13	US Census, Social Explorer
Percent of the labor force employed in construction, extraction, and maintenance	2005/09, 2009/13	US Census, Social Explorer
Percent of the labor force employed in production, and transportation	2005/09, 2009/13	US Census, Social Explorer
Percent of occupied housing units that are renter occupied units	2005/09, 2009/13	US Census, Social Explorer

Table 5. Descriptive Statistics for Control Variables in Multivariate Models

	County Data for Pooled Time Series Models (n=528)		County Data for Percentage Change Models (n=66)	
Variable	Mean (Std Dev)	Min-Max	Mean (Std Dev)	Min-Max
Population Density (2005/09)	296.2 (468.9)	13.4 - 3013.0	292.0 (469.7)	13.4 - 3013.0
Population Density (2009/13)	302.5 (476.9)	12.6 - 3044.8	298.3 (477.7)	12.6 - 3044.8
Percent Change	1.9 (3.0)	-6.0 - 13.2	2.0 (3.3)	-6.0 - 13.2
Percent Male 18-34 (2005/09)	10.7 (2.4)	8.4 - 22.9	10.9 (2.9)	8.4 - 22.9
Percent Male 18-34 (2009/13)	10.7 (2.6)	8.1 - 24.6	11.0 (3.1)	8.1 - 24.6
Percent Change	0.6 (4.2)	-13.5 - 14.4	0.7 (4.3)	-13.5 - 14.4
Percent Unemployed (2005/09)	6.4 (1.1)	3.9 - 8.8	6.5 (1.1)	3.9 - 8.8
Percent Unemployed (2009/13)	8.3 (1.4)	5.8 - 13.7	8.2 (1.4)	5.8 - 13.7
Percent Change	30.1 (20.6)	-13.9 - 105.7	29.6 (20.9)	-13.9 - 105.7
Percent Poverty (2005/09)	11.9 (3.1)	4.9 - 18.8	12.0 (3.1)	4.9 - 18.8
Percent Poverty (2009/13)	12.9 (2.9)	5.4 - 20.5	12.9 (3.0)	5.4 - 20.5
Percent Change	9.7 (12.2)	-15.4 - 38.8	9.8 (12.3)	-15.4 - 38.8
Percent Employment in Const/Extract/Maint (2005/09)	10.6 (2.3)	6.6 - 17.5	10.7 (2.3)	6.6 - 17.5
Percent Employment in Const/Extract/Maint (2009/13)	10.1 (2.5)	5.8 - 16.0	10.1 (2.5)	5.8 - 16.0
Percent Change	-4.8 (11.1)	-46.2 - 31.7	-5.4 (12.2)	-46.2 - 31.7
Percent Employment in Production/Transport (2005/09)	18.3 (4.9)	7.7 - 32.8	18.3 (4.9)	7.7 - 32.8
Percent Employment in Production/Transport (2009/13)	17.3 (4.5)	7.9 - 33.3	17.3 (4.5)	7.9 - 33.3
Percent Change	-5.0 (6.8)	-21.9 - 8.9	-5.2 (6.9)	-21.9 - 8.9

Appendix B: Typologies

Table 6. Listing of Counties by Typologies Used

Well Count Typology	***Counties***
No Wells	Adams, Berks, Bucks, Carbon, Chester, Cumberland, Dauphin, Delaware, Erie, Franklin, Fulton, Juniata, Lancaster, Lebanon, Lehigh, Mifflin, Monroe, Montgomery, Montour, Northumberland, Perry, Philadelphia, Pike, Schuylkill, Snyder, Union, York (27 counties)
Bottom Quartile (7 or fewer)	Bedford, Blair, Cambria, Columbia, Crawford, Huntingdon, Lackawanna, Luzerne, Warren, Wayne (10 counties)
Second Quartile (8-85)	Cameron, Centre, Clarion, Forest, Indiana, Jefferson, Mercer, Potter, Somerset, Venango (10 counties)
Third Quartile (86-292)	Allegheny, Armstrong, Beaver, Clearfield, Clinton, Elk, Fayette, Lawrence, McKean, Sullivan (10 counties)
Top Quartile (More than 292)	Bradford, Butler, Greene, Lycoming, Susquehanna, Tioga, Washington, Westmoreland, Wyoming (9 counties)
Well Density Categories	***Counties***
0 wells per 100 square miles	Adams, Berks, Bucks, Carbon, Chester, Cumberland, Dauphin, Delaware, Erie, Franklin, Fulton, Juniata, Lancaster, Lebanon, Lehigh, Mifflin, Monroe, Montgomery, Montour, Northampton, Northumberland, Perry, Pike, Schuylkill, Snyder, Union, York (27 counties)
0.01 – 0.80 wells per 100 square miles	Allegheny, Bedford, Blair, Cambria, Cameron, Clarion, Columbia, Crawford, Forest, Huntingdon, Indiana, Lackawanna, Lawrence, Luzerne, Mercer, Somerset, Venango, Warren, Wayne (19 counties)
Greater than 0.80 wells per 100 square miles	Armstrong, Beaver, Bradford, Butler, Centre, Clearfield, Clinton, Elk, Fayette, Greene, Jefferson, Lycoming, McKean, Potter, Sullivan, Susquehanna, Tioga, Washington, Westmoreland, Wyoming (20 counties)

*Calculations based on cumulative number of wells from 2005-2012

**Data source: PA Department of Environmental Protection

**Note the two classification systems are similar, in that the top two categories of the well count typology match the top category of the well density categories with two exceptions: Lawrence and Allegheny counties. These two counties fall into the lower half of the well density distribution.

Appendix C: Arrest Rates by County Typologies

Table 7. Annual Average County Mean Arrest Rates (per 100,000 residents) by Marcellus Shale Categories, 2005-2012

Minor Arrest Rate	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
No wells	1624	1649	1625	1563	1467	1441	1824	1459
1-7 Wells	1935	1935	1769	1683	1642	1621	1929	1553
8-85 Wells	2080	2175	2061	1896	1824	1810	2126	1801
86-292 Wells	1787	1778	1765	1753	1631	1598	2088	1870
Greater than 292 Wells	1620	1517	1361	1322	1225	1209	1644	1398
DUI Arrest Rate	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
No wells	386	414	420	439	435	422	429	415
1-7 Wells	4367	469	453	422	414	411	362	356
8-85 Wells	512	562	556	493	488	489	460	409
86-292 Wells	394	430	453	463	433	402	391	388
Greater than 292 Wells	394	421	422	431	403	418	419	420
Drug Arrest Rate	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
No wells	327	352	338	328	319	329	330	310
1-7 Wells	346	365	357	328	302	292	271	275
8-85 Wells	266	279	266	224	247	258	312	306
86-292 Wells	467	498	478	485	437	434	434	423
Greater than 292 Wells	268	262	236	244	246	237	232	241
Drunkenness Arrest Rate	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
No wells	224	222	232	227	227	228	225	222
1-7 Wells	308	321	324	303	298	286	266	246
8-85 Wells	262	287	296	299	266	249	243	236
86-292 Wells	243	228	263	246	231	221	231	253
Greater than 292 Wells	175	173	153	162	147	149	160	169
Disorder Arrest Rate	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
No wells	554	575	554	562	544	513	449	402
1-7 Wells	527	500	480	454	441	444	398	385
8-85 Wells	631	646	635	590	619	512	422	360
86-292 Wells	616	609	669	626	597	522	489	492
Greater than 292 Wells	471	463	432	430	400	399	404	416

Table 8. Descriptive Statistics for Percentage Change in Arrest Rates between 2007 and 2012 by Well Density Categories

	Percent Change in Minor Crime Arrest Rate 2007-2012	Percent Change in DUI Arrest Rate 2007-2012	Percent Change in Drug Abuse Violation Arrest Rate 2007-2012	Percent Change in Public Drunkenness Arrest Rate 2007-2012	Percent Change in Disorderly Conduct Arrest Rate 2007-2012
Well Density = 0 wells per 100 sq mi (n=27)					
Mean	-6.7	8.3	1.5	-3.2	-32.6
Std. Deviation	19.8	49.1	41.8	21.5	22.7
Minimum	-50.0	-39.0	-60.0	-56.0	-80.0
Maximum	47.0	176.0	127.0	38.0	12.0
Well density 0.01 – 0.80 per 100 sq mi (n=19)					
Mean	-12.6	-16.3	-5.7	-15.3	-32.2
Std. Deviation	17.7	23.5	47.2	21.0	24.3
Minimum	-46.0	-46.0	-68.0	-53.0	-68.0
Maximum	15.0	53.0	134.0	29.0	19.0
Well density = > 0.80 per 100 sq mi (n=20)					
Mean	-3.0	4.5	22.7	-4.6	-21.2
Std. Deviation	18.1	41.5	53.4	36.0	31.7
Minimum	-34.0	-45.0	-63.0	-75.0	-109.0
Maximum	36.0	97.0	175.0	100.0	27.0

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The Center for Rural Pennsylvania
625 Forster St., Room 902
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