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Does oil and gas development increase crime within UK local authorities?☆

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ABSTRACT

There is a renewed interest in expanding domestic oil and gas development in the United Kingdom (UK). However, the potential social consequences of this expansion are still unknown. Thus, the current study assesses whether the number of spudded oil and gas wells are correlated with violent and property crime rates within 69 local authorities between 2004 and 2015 (n = 828). Fixed effects regression analyses indicate that wells are positively correlated with violent crime rates. That is, each additional well is associated with a 1.5% increase in violent crime. When the analysis is limited to those local authorities that have constructed the most wells, the correlation between wells and crime increases as the boomtown literature might suggest. In particular, each additional well is associated with a 4.9% increase in violent crime and a 4.9% increase in property crime. We conclude by pointing out that this study stands as the first to empirically examine the relationship between oil and gas development and crime within UK local authorities over time and suggest that results have important implications for crime, social disorganisation and environmental justice.

1. Introduction

Global energy demands and a call to increase unconventional forms of natural gas extraction have led to a renewed interest in the relationship between oil and gas development and crime (Hultman et al., 2011). The present study responds to this interest by examining the relationship between oil and gas development and crime rates within UK local authorities between 2004 and 2015. The relationship between oil and gas development and crime in the UK is interesting for three reasons. First, UK policy-makers and industry are promoting the swift expansion of domestic natural gas development. For example, in January 2014 the UK's then Prime Minister David Cameron stressed gas extraction as one aspect of the government's new energy policy, noting, 'we're going all out for shale. It will mean more jobs and opportunities for people and economic security for our country' (Watt, 2014, 1). As oil and gas expansion is set to expand in the UK additional information about the potential consequences of oil and gas development on crime are warranted. Second, while a handful of studies have examined the relationship between natural gas extraction and crime in the US, there have been no studies of this potential relationship in the UK and it is unclear whether US findings can be extended to the UK (Hays et al., 2015). Therefore, additional studies of the relationship between oil and gas development and crime are needed in the UK for extension and comparison. Third, the present study can provide additional theoretical insight into the potentially disruptive consequences of extractive forms of development by examining crime as an outcome. This focus can be linked to contemporary environmental justice issues and debates (Freudenburg and Gramling, 1992).

Our analysis of oil and gas development and crime is divided into four sections. First, we draw upon the concept of boomtowns and social disorganization to explain why oil and gas development might be related to crime. We then provide a summary of the existing empirical studies that examine the relationship between oil and gas development and crime. Second, we describe the key variables used to examine the correlation between oil and gas development and crime. Third, we explain how we use these key variables to examine crime rates within local authorities in the UK. Finally, we draw some conclusions about the role of oil and gas development on crime rates and explore some potential implications of these findings for the political economy of crime and environmental justice studies.

2. Theoretical perspective & previous empirical studies

There is a common belief that oil and gas development can

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disorganise communities by causing the rapid congregation of people and money (O'Connor, 2015, 2017). The term 'boomtown' is historically used to describe natural resource development and its connection to crime. Nearly one hundred years ago historian Hagedorn (1921, 48) described Little Missouri (USA) as a 'boomtown' and 'villainous gateway to the bad lands [and full of] outcasts of society, reckless, greedy, and conscienceless; fugitives from justice with criminal records, and gunmen who lived by crooked gambling and thievery of every sort.' In the UK the term is also synonymous with the kind of social disorder that is perpetuated by rapid population growth (Brooks and Haworth, 1993; Calnan, 2011).

The notion of social disorganisation often associated with boomtowns can be traced back to Durkheim ([1893]1893). As communities change with the introduction of development, mechanical solidarity declines and leads to greater variation in community norms that facilitate higher rates of community problems such as suicide and crime (Durkheim [1893] 1984). Over time, Durkheim suggests that development can prevent social problems if institutions are correctly functioning and as mechanical solidarity gives way to organic solidarity in a move that strengthens regulative and integrative social forces (see also Shelley, 1981).

Despite the general modernization idea that development can lead to reductions in crime over time, most studies of community crime and oil and gas development tend to focus on the short term and negative aspects of development. Researchers such as Freudenburg (1979, 1984, 1992) have observed that oil and gas development can produce boomtown like conditions that sow the seeds for immediate increases in crime (Wilkinson et al., 1982). Researchers who examine oil and gas development on crime also suggest it is 'inherently disruptive' for communities. For instance, Luthra (2006) and Seydlitz et al. (1993) observe that social disorganisation associated with oil and gas development may be the mechanism that explains the relationship between extraction and crime. These observations about social disorganization acting as a mechanism in explaining crime are situated in Shaw and McKay's (1969) work in Chicago (USA). Shaw and McKay point out that rapidly changing populations will disrupt patterns of relationships within communities and create the kind of social milieu and community conflict that is ripe for crime and deviance (Shaw and Mckay, 1969). They note that social institutions are less effective within zones of transition because people know a smaller proportion of community residents and therefore have fewer social bonds that prevent crime (Shaw and McKay, 1969; see also Freudenburg, 1979). Social isolation may increase in areas where oil and gas development occurs because people have less contact with those people they do know, weakening social ties among residents (Freudenburg, 1979). Together, fewer bonds and weaker ties may create the social conditions for crime. Because of the decrease in the density of acquaintances, communities that are in transition must increasingly rely on formal social controls such as law enforcement to prevent unwanted behaviour (Clinard and Meier, 1975; Ruddell, 2011). This type of social control may lead to additional weakening of community bonds and can result in even more crime. These ideas about social disorganisation provide the theoretical grounding for most studies of oil and gas development and crime.

A handful of empirical studies have examined whether oil and gas development is correlated with crime. These studies can be classified according to their results. The first set of studies find evidence of a correlation between oil and gas extraction and crime. For example, Seydlitz et al. (1993) examined the impact of offshore oil and gas development on community crime rates. The researchers examine the impacts of offshore oil extraction wells in communities surrounding the Gulf of Mexico by looking at the price of oil and the number of wells drilled in Louisiana parishes between 1956 and 1981. They find that homicide rates were higher in those parishes with the most wells. This positive correlation between oil development and crime was more intense in those parishes where a greater percentage of residents were employed in the oil industry and therefore receiving higher oil and gas wages. Consistent with social disorganization theory, the researchers also find that homicide rates were highest during those periods of rapid oil and gas development (Seydlitz et al., 1993, 1999).

Ruddell and Ortiz (2014) recently examined property and violent crime in oil and gas producing counties in Montana and North Dakota. The researchers compared (1) property and violent crime rates in 26 oil producing counties to crime rates in a matched sample of 26 non-producing counties and (2) property and violent crime pre- and post- 'gas booms' in all counties. The researchers discovered no statistically significant differences in crime rates when comparing across communities by level of development. They did, however, discover a sharp increase in crime over time in oil producing counties. Specifically, both violent and property crime increased in oil producing counties between the years of 2006 and 2012. For violent crime, the increase was 19% and for property crime, the increase was 12%. In contrast, property crime decreased by 22% and violent crime decreased by 26% in non-producing counties pre- boom (2006–2008). Interestingly, the only demographic difference between counties was population change during the boom years (2008–2012). The population in non-producing counties increased by 0.13%, while the population of oil producing counties increased by 1.85%. The overall population, percentage of males and per capital income did not differ between counties.

Recently, Price et al. (2014) examined the relationship between the number of oil and gas wells and property and violent crime rates in 210 counties in Pennsylvania, Ohio and West Virginia (US). While the study found little evidence that increased oil and gas extraction related development led to population growth in a boomtown fashion, there was, nevertheless, a 17.7% increase in violent and 10.8% increase in property crime in high drilling counties between the years of 2005 and 2012.

A second set of empirical studies finds mixed evidence that oil and gas development leads to higher levels of crime. For instance, Covey and Menard (1983) conducted one of the first longitudinal studies of crime rates in Colorado (US) during the 1970s and compare the change in crime rates between counties with and without oil and gas development over time. The researchers found that between 1970 and 1979 crime increased more substantially in oil and gas development counties than those without development. Covey and Menard's results persist even after controlling for population changes. However, the results were not consistent for all types of crime as Covey and Menard found that oil and gas development was associated with a decrease in homicide rates.

Komarek (2015) also recently examined the potential impact of unconventional gas extraction (or fracking) in Pennsylvania (US) counties in the Utica and Marcellus shale formations between the years of 2004 and 2012 and discovered that the number of unconventional wells drilled is positively correlated with violent crime (i.e., murder, rape, robbery and assault). Importantly, Komarek (2015) discovered that high-development counties (i.e., those that had more than 75 wells) had violent crime increases that were 30% higher than low-fracking counties. Importantly, the number of fracking wells was related to violent crime in both high- and low-fracking counties between the years of 2004 and 2012. Despite the rather strong correlations between violent crime and fracking wells, Komarek (2015, 31) found that property crime was uncorrelated with the number of fracking wells. Finally, James and Smith (2017) examined the relationship between geographical shale formations and crime rates in US counties between 2000 and 2011. When comparing shale 'plays' (n = 378) and 'booming plays' (n = 215) to non-shale counties the researchers determined there is a robust correlation between petroleum development and crime. Moreover, the 'booming' play counties had greater increases in crime than the play counties, suggesting that those communities with more rapid levels of development also experienced higher crime rates than those communities with lower levels of development. Rather than looking at aggregate crime types, James and Smith examined rates for specific types of crime as reported by the Federal Bureau of Investigation (i.e., murder, rape, robbery, assault, larceny, burglary and motor vehicle theft). The researchers report that violent crime rates are more likely than property crime rates to surge during the energy booms. These violent crime increases appear to be independent of social and economic changes in variables such as gross domestic product, mining employment, population size, percentage male, and percentage of the population that is young.

A third set of studies fail to find any positive correlation between oil and gas development and crime. Wilkinson et al. (1984) examine the relationship between violent crime and oil and gas development in nonmetropolitan counties between 1970 and 1978 in energy producing states in the US (i.e., Arizona, Colorado, Montana, New Mexico, Utah and Wyoming). The results of their analysis produced no evidence that oil and gas development are associated with crime. The researchers concluded that there is little support for the position that crime is caused by social disorganization and instead suggest that longstanding structural differences such as low levels of unemployment and high rates of poverty distinguish between crime rates among communities. Luthra et al., 2007; see also Luthra, 2006) also examined the relationship between offshore oil and gas development and crime rates between 1974 and 2004 in twelve Louisiana parishes where a significant number of residents were employed in oil and gas development. These oil and gas parishes were then compared to 24 similar parishes where no oil and gas development existed. Contrary to expectations, Luthra et al. (2007, 121) found that 'as oil activity increases over time and across parishes, the levels of homicide and aggravated assault significantly declines [and that] oil activity is not significantly associated with any of the other crime offences.' As a result, the researchers claim that oil and gas development does not lead to community conditions or the type of social disorganisation that produces increases in crime but may, instead, be beneficial to communities.

In total, existing studies that examine the relationship between oil and gas development and crime lead to different conclusions. That is, one set of studies finds a consistent relationship between oil and gas development and all types of crime; a second set of studies finds a relationship between oil and gas development and violent crime (except homicide); a third set of studies finds little evidence of a positive relationship between oil and gas development and crime. Unfortunately, nearly all quantitative studies focused exclusively on the relationship between oil and gas development and crime rates are based in the US. Due to the diversity of findings and the lack of research within the UK, additional analysis is warranted.

3. Methodology

We study the correlation between natural gas development and crime within local authorities in the UK between 2004 and 2015. As Fig. 1 illustrates, there were a total of 300 new oil and gas wells developed in the UK between the years of 2004 and 2015. Oil and gas development increases considerably between 2004 (n = 18) and 2008 (n = 45), at which point the number of newly established wells decline until 2015 (n = 7). To conduct our analysis, we assembled panel data for crime rates, the number of natural gas wells, and control variables for 69 local authorities located in England, Scotland and Wales (listed in Appendix A).

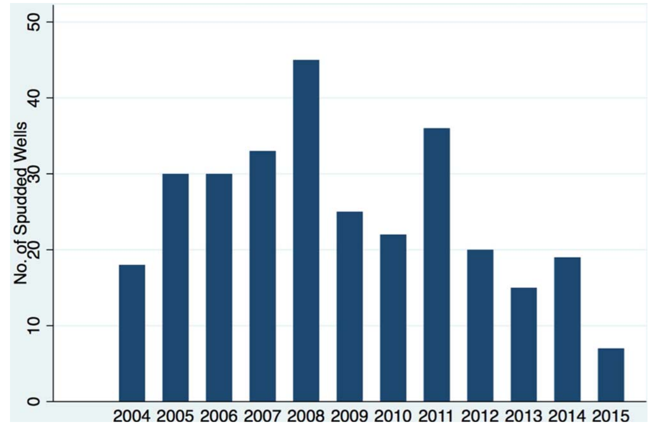

Fig. 1. Number of Spudded Oil and Gas Wells, 2004–2015.

We chose to study these 69 local authorities since they are the communities where oil and gas development takes place and because local authorities influence development decisions. In total, we collected 12 years of data for each local authority. We pooled the observations for the 69 local authorities so that the data set consists of 828 community-year observations. Crime data are not available every year for every local authority, consequently, the number of community-crime years varies from 734 (for violence) to 777 (for violent crime, property crime and homicide). All variables used in our statistical analysis are described below with descriptive statistics for the overall sample presented in Appendix B. We now turn to the description of the variables used in our models.

3.1. Dependent variables

There are four different dependent variables in this study: homicide rates (*Homicide*), violent crime rates (*Violent Crime*), violence rates (*Violence*) and property crime rates (*Property Crime*). All crime rates are measured as the number of offences per 100,000 residents in any given year and are transformed using the natural logarithm to produce better fitting models and adjust for non-linear relationships. Data on crime come from different sources depending on the country. In England and Wales crime data come from the *Recorded Crime Data at Community Safety Partnership/Local Authority Level* data files obtained from the Office of National Statistics (https://www.ons.gov.uk). In England and Wales the homicide rate is calculated by computing the number of homicides per 100,000 residents; the violent crime rate is calculated by combining the total number 'homicide', 'robbery', 'sexual offences', 'violence with injury' and 'violence without injury', dividing by the resident population of the local authority and multiplying by 100,000; the violence rate is calculated by dividing the sum of crimes of violence with and without injury and dividing by the population; and the property crime rate is calculated by combining 'domestic burglary', 'non-domestic burglary', 'shoplifting,' 'theft from the person' and 'all other theft offences,' dividing by the resident population local authority and multiplying by 100,000. In Scotland, crime data come from the Scottish Government's *Recorded Crime in Scotland* datasets (http://www.gov.scot/Topics/Statistics/Browse). In Scotland, the homicide rate is calculated by computing the number of homicides per 100,000 residents in local authorities. The violent crime rate in Scotland's local authorities is computed in the same way as for England and Wales.' The

Table 1
Summary of Relationships (Pearson's *r*) between Crime and Number of Wells in Local Authorities, 2004–2015.

	Homicide No. Local Authorities (%)	*Violence* No. Local Authorities (%)	*Violent Crime* No. Local Authorities (%)	*Property Crime* No. Local Authorities (%)
Positive & Significant	5 (7%)	6 (9%)	9 (9%)	24 (35%)
Positive & Insignificant	26 (38%)	33 (49%)	34 (49%)	11 (16%)
Negative & Significant	3 (4%)	11 (16%)	17 (25%)	20 (29%)
Negative & Insignificant	34 (49%)	13 (19%)	13 (19%)	13 (19%)
Missing	1 (1%)	6 (9%)	1 (1%)	1 (1%)
	100%	100%	100%	100%

property crime rate in Scotland's local authorities is determined by combining 'housebreaking,' 'theft by opening a lockfast place,' 'theft from a motor vehicle,' 'theft of a motor vehicle' and 'shoplifting and other theft.'

One potential problem with different sources of crime data is the inability to make comparisons across local authorities. That is, differences in crime rates between local authorities in different countries in the UK could simply be the result of administrative differences in the coding and classifying of crime data (McCleary et al., 1982; see also Soothill and Francis, 2012). While definitions of crime may vary across England, Wales and Scotland, there are ways to minimize the problem of inconsistency in statistical analysis of crime data. For example, variations across local authorities are not likely to be problematic when examining the correlates of crime within local authorities. This within effects approach is the one we take to help solve the problems of inconsistent measurements across local authorities. The use of fixed effects panel regression follows our theoretical test of the relationship between oil and gas development and crime where we are interested in changes within, rather than between, local authorities. The fixed effects approach minimises problems associated with the different categorisations of violent and property crime by essentially controlling for all potential confounders that differentiate local authorities. Nevertheless, to examine the country level differences in crime among the local authorities examined in this study in more detail we conduct a simple *t*-test for difference of means on average violent and property crime rates. As expected, and noted in international crime data, Scotland local authorities have higher homicide rates than England and Wales local authorities (see Soothill and Francis, 2012). The average homicide rate among Scotland local authorities in this study is 2.04 per 100,000 while the homicide rate among England and Wales is 0.98 per 100,000 ($t = 6.2$, $p < 0.01$). In the case of property and violent crime, England and Wales, both have higher reported levels of crime than Scotland in the local authorities that we study. For instance, the average annual property crime rates are 3185 per 100,000 residents in England and Wales while they are 2078 per 100,000 residents in Scotland for the local authorities we study ($t = 5.3$, $p < 0.01$). Again, this is generally accepted as an accurate representation of property crime data across these countries (*Scottish Crime and Justice Survey* 2012–2013, 2014). Finally, the average annual violent crime rates are 246 per 100,000 in Scotland and 1268 per 100,000 in England and Wales ($t = 13.9$, $p < 0.01$). Unfortunately, there are no Scottish equivalents of the England and Wales indicator of violence with and without injury. Thus,

Table 2
Fixed-Effects Regression Coefficients (*b*) and Robust Standard Errors (SE) for Variables Estimating UK Crime Rates, 2004–2015[a].

	Homicide		*Violence*		*Violent Crime*		*Property Crime*	
	b	SE	*b*	SE	*b*	SE	*b*	SE
No. Wells	−0.042	0.035	.020*	0.0079	.015*	0.0072	0.0078	0.0079
Males 16–24	0.15	0.11	0.0037	0.0076	0.0036	0.0071	0.0056	0.0056
Population Density	0.26	0.22	0.021	0.034	−0.046	0.032	−0.10**	0.025
Job Density	−0.34	1.4	0.029	0.14	0.018	0.13	0.021	0.086
Unemployment	−0.021	0.057	−0.0085	0.0048	−0.0085	0.0045	−0.0026	0.0038
Income (1,000s)	0.062	0.075	−0.0056	0.0053	−0.0056	0.0049	−0.0023	0.0038
Year (vs. 2004)	–	–	–	–	–	–	–	–
2005	0.60	0.39	.10**	0.021	.084**	0.019	−0.035**	0.012
2006	−0.19	0.31	.092**	0.030	.071*	0.027	−0.05**	0.017
2007	0.20	0.40	−0.014	0.031	−0.025	0.029	−0.16**	0.020
2008	0.30	0.44	−0.071*	0.031	−0.081**	0.029	−0.23**	0.020
2009	0.26	0.48	−0.12*	0.045	−0.13**	0.044	−0.35**	0.036
2010	0.08	0.56	−0.14**	0.040	−0.15**	0.038	−0.46**	0.025
2011	−0.22	0.54	−0.21**	0.040	−0.19**	0.037	−0.51**	0.027
2012	−0.48	0.50	−0.25**	0.039	−0.25**	0.036	−0.62**	0.027
2013	−0.17	0.56	−0.23**	0.040	−0.21**	0.038	−0.65**	0.028
2014	−0.35	0.51	−0.11**	0.042	−0.09**	0.041	−0.66**	0.027
2015	0.19	0.52	.13**	0.045	.16**	0.042	−0.63**	0.028
Constant	0.24	2.1	7.2**	0.26	7.4	0.24	8.9	0.17
N	777		734		777		777	
F	2.3*		29.5**		29.4**		92.6**	
Pseudo R^2	0.06		0.46		0.51		0.88	

Note: $^{**}p < 0.01$, $^{*}p < 0.05$; 2-tailed.

[a] Crime rates are expressed in natural log (ln) units. Thus, we interpret the exponentiated regression coefficients (*b*) as a percentage change in the crime rate corresponding to a 1-unit change in the independent variable. For example, we expect to see about a 2% increase in violence within local authorities with each additional well (i.e., exp (.20) = 1.02).

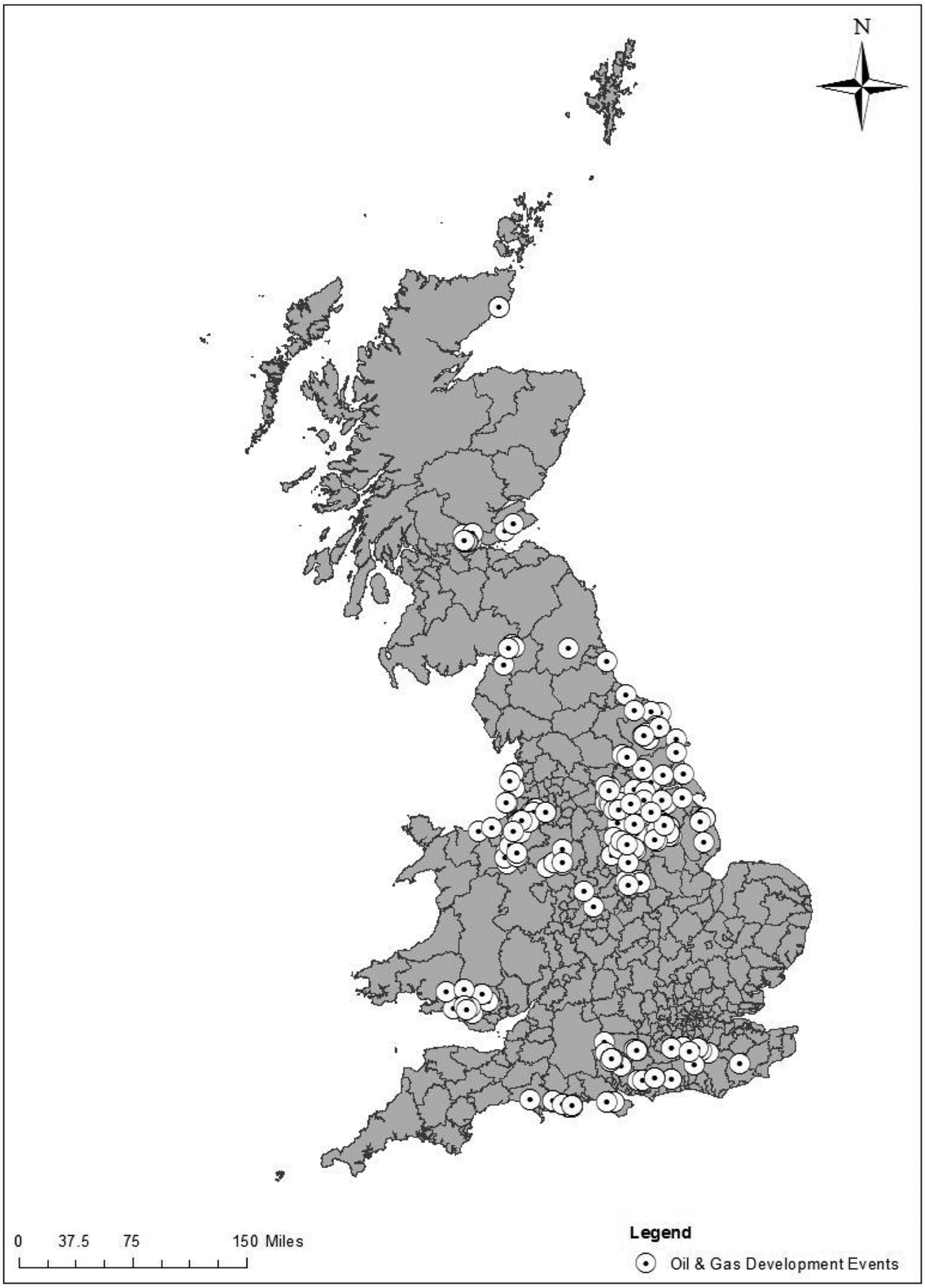

Fig. 2. Distribution of Spudded Oil and Gas Wells in England, Scotland and Wales, 2004–2015.

the analysis for the variable *Violence* is limited to England and Wales local authorities (see Tables 1 and 2).

3.2. Independent variable

The Department of Energy and Climate Change recorded the establishment of at least one oil and gas well in 69 local authorities between 2004 and 2015. Thus, the independent variable in this study represents the number of existing oil and gas wells in a local authority in any given year (*No. Wells*). These data are made available by the Oil and Gas Authority through their *Onshore Well Data File* (http://data-ogauthority.opendata.arcgis.com).The information contained in that data file includes the location (latitude and longitude) of each oil and gas wells and the date wells were permitted, spudded, began operation and ended operation. We mapped the location of each well within each local authority using GIS technology. This approach allows researchers to produce a variable measuring the number of oil and gas producing wells in each local authority in any given year. The locations of the oil and gas wells examined in this study are displayed in Fig. 2.

As noted in Fig. 2, oil and gas wells are generally distributed within the midlands and south of London as well as in rural parts of Scotland and Wales. For the purposes of this study we mark the year a well was 'spudded' as the beginning of that portion of oil and gas development in a local authority. A well is generally 'spudded' on the date that drilling begins. Research suggests that the social consequences of oil and gas development often emerge shortly after extractive industries begin production (Freudenburg and Frickel, 1994). Thus, the spud date marks an important point in the oil and gas development process. The spud date is also typically used by researchers who study the economic impact of oil and gas development (e.g., Muehlenbachs et al., 2015). Finally, as previously noted, if oil and gas development is correlated with crime, then as the number of wells increase within a local authority, the crime rate should also increase.

3.3. Control variables

Crime rates within local authorities are likely to be associated with factors other than the number of oil and gas production wells. Thus, we adjust the relationship between the number of oil and gas wells and crime using several time variant control variables. The choice of controls is based on prior research on development and crime. Specifically, we study oil and gas development and crime within local authorities while controlling for (1) the percentage of young males, (2) population density, (3) job density, (4) household unemployment, (5) median household income and (5) year. These variables were obtained using the 'query' feature in the Office of National Statistics' *Nomis Database* (https://www.nomisweb.co.uk). We account for missing data among the control variables using multiple imputation methods via the 'mi' command in version 15 of Stata (Carlin et al., 2003). As a result, Stata imputed 100 additional datasets with random error terms to estimate between 33 (for household income) and 63 (for young males) missing values.

We measure the percentage of the population in each local authority that is male and between the ages of 16 and 24 (*Males 16–24*). This variable is used as a loose indicator of a relatively crime prone population that may be more likely to engage in crime and drive up crime in local authorities (Farrington, 1986). We hypothesise that as the percentage of these males increase within a local authority, crime in that local authority is also likely to increase. Second, we control for population density. Population density is measured as the number of people per square kilometer (*Population Density*). We suggest that many times oil and gas development tends to be situated in relatively remote and locations where population density is low.

Criminologists have sometimes suggested that low density communities may have lower crime rates than high density communities because people are more likely to know one another (see Shichor et al., 1979). Thus, density is important in studies of oil and gas development and crime (see Wilkinson et al., 1984). Since we are measuring change within local authorities, examining the variable *Population Density* is essential as it reflects changes in heterogeneity that may occur in authorities over time and may influence delinquent behavior (Freudenburg, 1979).

We also create a variable *Job Density* that measures the number of vacant jobs in a local authority relative to the number of people that are classified by the government as able to work (see *Nomis*). This ratio is greater than "1″ if there are more jobs than job seekers and less than "1″ if there are more job seekers than jobs. We hypothesise that increases in the availability of jobs should lead to increases in the rates of crime within local authorities over time. If oil and gas development increases job availability though the creation of industry and service jobs, this should help explain the relationship between oil and gas development and crime. As an additional measure of employment status, we measure household unemployment (*Unemployment*) that looks the percentage of households where all or some of the members are unemployed. Household unemployment measures the percentage of households within a local authority where at least one householder is unemployed but able to work. We examine the economic conditions within a local authority by looking at median household income in thousands of pounds (£) (*Median Income*). Local authorities where residents have lower average incomes may be more open to oil and gas development than local authorities that have higher incomes. Thus, other things being equal, low income authorities may be more likely to attract oil and gas development and, because of relatively low incomes, have higher crime rates because these communities may be more socially disorganised (see Bursik and Grasmick, 1993). Controlling for income as a potential source of spuriousness is important in any study of oil and gas development and crime. Finally, as we are conducting a fixed effects analysis within local authorities we also control for time (*Year*). That is, crime may be increasing or decreasing over time in a way that has nothing to do with development or other control variables included in the model (Wilkinson et al., 1984). By adjusting the models by *Year* as a categorical variable we are able to capture any potential non-linear trends in crime that could, if left unaccounted for, be attributed to oil and gas development related crime.

4. Analysis

Unlike cross-sectional analyses that examine variation in crime between local authorities, we are interested in the potential correlation between oil and gas development and crime within local authorities. For this reason we use fixed-effects regression using '*xtreg*' with the 'fe' option in Stata to hold constant any stable characteristics between local authorities (Allison, 1994; Greene, 2012). This approach allows us to establish if there is something unique about the impact of oil and gas development within local authorities. The fixed-effects model can be specified as follows when 'i' represents local authorities and 't' represents years:

$$\mathrm{Y(it)} = \mathrm{X(it)}\mathit{Beta} + \mathit{Alpha}(\mathrm{i}) + \mathit{Mu}(\mathrm{it}); \quad \text{for} \quad \mathrm{i} = 1\text{–}69 \quad \text{observed at} \quad \mathrm{t} = 2004\text{–}2015$$

Where Y(it) is the dependent variable 'crime', X(it) is a 1 by K matrix of the number of spudded oil and gas wells and controls, *Beta* is a K-dimensional column vector of parameters, *Alpha*(i) represents all unobserved time-invariant local authority variables that influence Y(it), and *Mu*(it) is the error term.

Because crime has both increased and decreased in UK local authorities between the years of 2004 and 2015 we have also, as noted, included a control that measures for this trend (i.e., *Year*) in each model we estimate. Despite our best efforts to control for trends in these crime data within local authorities, there may still be the potential for problematic serial correlation in the models. To test for this potential violation we employ the Wooldridge test for autocorrelation. The Wooldridge test uses the F-distribution to test the null hypothesis that no autocorrelation exists in a model. In the models reported here we find no evidence of autocorrelation and the therefore conclude that the fixed effects standard errors we estimate do not suffer from problematic autocorrelation (Drukker, 2003). We also compute robust standard errors for each model estimated to account for the clustering of observations within local authorities and produce more efficient estimates that minimize heteroscedasticity.

Prior to presenting the results for the fixed effects panel regression analysis, we present simple bivariate correlations between homicide, violence, violent crime, property crime and the number of wells for each local authority. These bivariate correlations are important because they set the stage for the multivariate analysis and demonstrate initial patterns of relationships between crime and oil and gas development within each local authority. This approach shows that the relationship is tenuous as sometimes the correlations are positive and sometimes negative. Given there are only twelve years of data in each local authority ($n = 12$) it is not surprising that many of the relationships are not statistically significant.

Table 1 displays results for Pearson's r correlations between each type of crime and the number of wells within each local authority between 2004 and 2015. As Table 1 illustrates, the bivariate relationship between crime and oil and gas development across England, Wales and Scotland is complex. In some local authorities, the correlations are positive, suggesting that development could increase crime. In other local authorities, the correlations are negative, suggesting that development may reduce crime.

Importantly, when examining Table 1, the correlations that are positive and significant outnumber those that are negative and significant in the case of property crime only. Nevertheless, the number of local authorities where increases in the oil and gas development are associated with increases in crime tend to outnumber those where oil and gas development is associated with decreases in crime (i.e., *violence*, *violent crime* and *property crime*). In short, Table 1 shows the complexity of the association and does not suggest any definitive answer to the question of whether oil and gas development increases crime. For this reason, it is important to examine that relationship considering other important variables that may influence crime within local authorities to help provide a more definitive explanation about the potential relationship between oil and gas development and crime.

Table 2 provides a more complex analysis though the multivariate fixed effects results that test the relationship between oil and gas development and crime when controlling for the percentage of young males, population density, percentage of unemployed households, median household income, job density and time.

The results in Table 2 are largely repetitive of the trends in the bivariate results reported in Table 1. However, there are some major differences in the two sets of findings. First there is a positive and statistically significant correlation between the number of oil and gas wells violence and violent crime rates. More specifically, the coefficients in Table 2 suggests that an each additional oil and gas well in a local authority is associated with a 2 percent increase in violence within local authorities between 2004 and 2015 ($p < 0.05$). It is important to note that our measure of violence includes assaults, harassment and vehicle offences that cause injury. Thus, this finding is not necessarily surprising as other studies suggest that traffic crime and 'pub brawls' are especially problematic in areas where oil and gas is rapidly developing (Carrington et al., 2010; Price et al., 2014; Scott et al., 2012; Ruddell, 2011). In the case of violent crime rates (Table 2), the results are also statistically significant and suggest that each additional oil and gas well is associated with a 1.5 percent increase violent crime ($p < 0.05$). Again, these results are consistent with US-based studies that find that violent crime is positively associated with oil and gas development (Komarek, 2015). As noted by the coefficients in Table 2, the substantive impact of these increases, while consistent with other similar studies, are still rather small. Nevertheless, when multiple wells are established, increases in crime could become quite large. In the context of Fig. 1, however, the growth in new wells across the UK is rather modest and very few local authorities experienced an extensive proliferation of development during the time-period under investigation. In particular, there were never more than 59 oil and gas wells operating at one time in any one local authority between the years between 2004 and 2015. Thus, increases in crime due to this development are likely incremental and reflect modest growth in oil and gas development as opposed to more rapid boomtown growth.

The results in Table 2 are also important as they suggest that there is no empirical evidence that oil and gas development is correlated with homicide rates or property crime rates within UK authorities. This situation is not necessarily surprising given past research findings (e.g., Covey and Menard, 1983; Komarek, 2015) but it is important to highlight this finding as the lack of statistical significance suggests that oil and gas development may not influence all types of crime.

Finally, in the case of the crime models presented in Table 2 it is certainly the case that *Year* is the best predictor of crime. Importantly, except for homicide, crime appears to increase in 2005 and 2006 (when compared to 2004) and then decreases between 2007 and 2014. There is a slight increase in violence and violent crime in 2015 (when compared to 2004). This finding documenting a rather sustained drop in violent and property crime is consistent with national trends lending credibility to these findings.

5. Discussion & conclusions

The Economic Affairs Committee (EAC) report to the House of Lords recently asked if oil and gas development 'fears that have been raised of serious adverse consequences for the health and for the environment, locally and nationally, have substance?' (EAC, 2014). Notably missing from the report's call for investigation are the potential social impacts of oil and gas extraction. Crime is one important social impact that has yet to be considered in the policy to expand oil and gas extraction across the UK. Our research has drawn upon criminological tradition and its emphasis on the concept of social disorganisation to focus on the neglected issue of crime in local authorities where oil and gas development is occurring. We find that the number of oil and gas extraction wells are positively correlated with violent crime rates in England and Scotland between the years of 2004 and 2015 within 69 local authorities that contain at least one spudded well. In particular, each additional spudded well corresponds to a 1.5 percent increase in violent crime. Thus, there is potential for oil and gas development to increase violent crime.

We situate our findings regarding oil and gas development, social disorganisation and crime within the political economy of crime and environmental justice. In particular, researchers such as Stretesky et al. (2013, Ch.5) have proposed that the extraction of natural resources (especially coal, natural gas and oil) is not only connected to social disorganisation, but social inequality as well. Moreover, researchers such as Foster et al., 2011 suggest that natural resource extraction is critical to the maintenance of capitalism. This is the case because capitalism requires endless growth and wealth accumulation that demand accelerated natural resource extraction (Foster et al., 2011; Klein, 2015). This growth imperative is at odds with environmental sustainability and social justice. That is, increasing levels of extraction create additional environmental degradation and intensify environmental injustice (Gould et al., 2008). In particular, environmental justice ideals are met when all people are (1) included equally in environmental decision-making (2) share environmental benefits and (3) are protected from the unequal and negative impacts of environmental hazards (Bullard and Johnson, 2000). As the geographic distribution of oil and gas development in the UK might suggest, this is not occurring. First, oil and gas reserves are not equally distributed across the UK landscape. This is an important issue because oil and gas reserves can be viewed as a 'curse' (Sachs and Warner, 2001).

When it comes to crime, this approach is highlighted by the treadmill of crime perspective developed by Stretesky et al. (2013). More recently the relationship between crime, social disorganisation and inequality has been expanded upon by Lynch and Boggess (2016); see also Lynch and Michalowski, 2006). In particular, Lynch and Boggess (2016) suggest that when social disorganisation is interpreted within the context of the needs of capitalism, it may help explain the distribution of crime, poverty and inequality. When it comes to the development of oil and gas wells across the UK, our interpretation of social disorganization is similar to the views of Lynch and Boggess. In the present analysis we suggest that the distribution of social disorganization may be encouraged by oil and gas development and potentially contribute to crime. As a result, communities that mine oil and gas are more likely to suffer from the consequences of that resource development. Second, the wealthiest communities may be better able than the poorest communities to resist oil and gas development and the social disorganisation that accompanies that development (Kubrin and Weitzer, 2003). In the UK, oil and gas development is often contested and it is not unusual for communities to oppose the construction of wells (see Jones et al., 2015). Wealthy communities can translate their wealth into a power of resistance for the common good and are more likely to effectively oppose oil and gas development (Gould et al., 1996). As a result, the spatial distribution of extraction is unevenly distributed across the landscape, constrained by its physical location and the socio-economic power of communities. The treadmill of crime interpretation of oil and gas development has yet to be empirically tested. That is, we study relationship between wells and crime within and not between local authorities in order to tease out the potential causal relationships between the oil and gas development and crime. However, future environmental justice research could be designed to examine community power dynamics to better understand the implications and distribution of oil and gas development when it comes to social disorganisation and violence (Kubrin and Weitzer, 2003).

Notably, and consistent with the US studies, our findings concerning the relationship between oil and gas development do not suggest oil and gas development are related to homicide or property crime rates (Covey and Menard 1983; Komarek, 2015; James and Smith, 2017). Thus, all types of crime do not appear to be influenced oil and gas development. Importantly, while our findings concerning the lack of a relationship between oil and gas development and property crime are consistent with previous research, they are also a bit puzzling. What could explain these mixed results concerning violent crime, homicide and property crime? There are three potential answers to this question. First, previous US research and the definition of crime may help answer this question. That is, violence rates in this study include traffic related crimes and pub brawling events. In the US, researchers have noted that it is precisely these types of events that are the most likely to be related to oil and gas (and especially boomtown) development. For instance, Ruddell and Ortiz (2014) notes that residents and police suggested that aggressive, impaired or dangerous driving was especially problematic. Other qualitative studies in the UK also report similar types of observations (Carrington et al., 2010; Smith and Christou, 2009). Second, it could also be the case that there is simply not enough oil and gas well development to impact property crime and homicide. Third, it could be that we have not adequately captured the impact of oil and gas development within local authorities. To examine support for the second and third explanations we conducted two additional post-hoc analyses (shown in Appendix C). First, we divided our sample based on expanding and contracting oil and gas development within local authorities. Next, we estimated the impact of the number of oil and gas wells in each sample (expanding local authorities and contracting local authorities) to see if the correlations between wells and crime changed. Our results suggest some support for the proposition that crime is only a problem in local authorities that are expanding production (i.e., boomtowns). In fact, within the expanding authorities each additional well is associated with a 4.9 percent increase violent crime. Moreover, the number of wells spudded is now also statistically significant in the property crime rate models we estimate (Appendix C). In particular, each additional spudded well is also associated with a 4.9 percent increase in property crime within those local authorities that build more wells. The coefficient for murder remains statistically insignificant. In short, while there were only 9 local authorities where spudded wells outpaced well closures between 2004 and 2015, these authorities produce the strongest correlations between the number of wells and property and violent crime (see Appendix C).

Second, we examine the potential that Table 2 results for property crime and homicide may be the result of using the number of wells as an indicator of oil and gas development. As an alternative oil and gas development indicator we also gathered data on employment from the UK's Office of National Statistics (https://www.ons.gov.uk) for the employment category "process, plant and machine operatives" (Major Group 8). While this measure of oil and gas development is far from perfect, it does include the number of employees working in energy extraction occupations and therefore offers an alternative indicator to the number of wells. We include this employment indicator as an additional predictor variable in the models we estimate in Table 2.[1] These post-hoc results in Appendix C provide little evidence that poverty and homicide are insignificant because of the way we operationalise oil and gas development. That is, employment is insignificant in the Models in Appendix C and the coefficients for oil and gas remain similar to those presented in Table 2. Unfortunately, the crude measure of oil and gas employment (though the only one available over time at the local authority level) is not likely a sufficient test of this alternative explanation for our lack of statistically significant findings. However, when possible future studies should attempt to include alternative measures of oil and gas development to measure different dimensions of development. For instance, the size of an oilfield or more direct measure of oil and gas employment may produce different and more robust findings.

In the end, there are no studies, of which we are aware, that have examined the empirical relationship between oil and gas development and crime within UK local authorities. However, given the potential social consequences facing oil and gas communities such an investigation is warranted. We recommend that as the UK's demand for energy continues to rise that criminologists should explore if, and how, forms of energy development might produce conditions within communities that can lead to an increase in crime. As we have shown, answering that question will provide important insight into the social consequences of oil and gas development, including a better understanding of environmental injustice in the UK.

[1] We would like to thank an anonymous reviewer for pointing out an alternative for measuring oil and gas development that may be more compatible with social disorganisation theory.

Appendix A

Table A1

Table A1
Local Authorities Included in the Study (2004–2015).

Allerdale	Falkirk	North East Lincolnshire	Sevenoaks
Barnsley	Fife	North Kesteven	St. Helens
Basingstoke and Deane	Flintshire	North Lincolnshire	Staffordshire Moorlands
Bridgend	Fylde	North Warwickshire	Stoke-on-Trent
Caerphilly	Guildford	Northumberland	Sunderland
Carlisle	Hambleton	Nottingham	Swansea
Charnwood	Highland	Preston	Tandridge
Cheshire West and Chester	Horsham	Purbeck	Test Valley
Chichester	Isle of Wight	Redcar and Cleveland	Tunbridge Wells
Clackmannanshire	Knowsley	Reigate and Banstead	Wakefield
Denbighshire	Lichfield	Rhondda Cynon Taf	Warrington
Derbyshire Dales	Melton	Rotherham	West Dorset
Doncaster	Merthyr Tydfil	Ryedale	West Lancashire
Dumfries and Galloway	Mid Sussex	Salford	West Lindsey
East Hampshire	Mole Valley	Scarborough	Wigan
East Lindsey	Neath Port Talbot	Sefton	Winchester
East Riding of Yorkshire	Newcastle-under-Lyme	Selby	Wrexham

Appendix B

Table B1

Table B1
Descriptive Statistics: Bivariate Correlations, Minimum, Maximum, Mean and Standard Deviation.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Homicide	1.000										
(2) Violence	0.751*	1.000									
(3) Violent Crime	0.168*	0.993*	1.000								
(4) Property Crime	0.276*	0.302*	0.755*	1.000							
(5) No. Wells	−0.024	−0.053	−0.084*	−0.040	1.000						
(6) Males 16 to 24	0.061	0.265*	0.329*	0.249*	−0.070	1.000					
(7) Population Density	0.222*	0.468*	0.525*	0.476*	−0.032	0.469*	1.000				
(8) Job Density	−0.033	0.008	0.090*	−0.059	0.043	0.090*	0.015	1.000			
(9) Unemployment	0.091*	0.142*	0.132*	0.116*	−0.030	0.339*	0.402*	−0.285*	1.000		
(10) Median Income	−0.182	−0.393*	−0.314*	−0.510*	−0.112*	−0.091*	−0.133*	0.313*	−0.209*	1.000	
(11) Year	−0.067	−0.153*	−0.153*	−0.566*	−0.036	0.143*	0.014	0.039	0.334*	0.449*	1.000
Minimum	0	170.8	114.61	548.3	0.00	2.81	0.08	0.46	1.1	13050	2004
Maximum	11.36	2990.3	3491.30	11677.3	59.00	10.56	42.75	1.26	15.0	31217	2015
Mean	1.05	1125.6	1203.36	3114.6	2.31	5.68	5.68	0.76	6.1	19864	2010
Standard Deviation	1.18	449.5	561.33	1448.6	5.48	1.17	6.94	0.15	2.7	2998	3.74

*p < 0.05.

Appendix C

Tables C1 and C2

Table C1
Post-Hoc Fixed-Effects Regression Coefficients (b) and Robust Standard Errors (SE) for Number of Oil and Gas Wells on Crime Rates, by Local Authorities that are (1) Expanding and (2) Contracting Oil and Gas Development (2004–2015) [a].

	Homicide		*Violence*		*Violent Crime*		*Property Crime*	
	b	SE	*b*	SE	*b*	SE	*b*	SE
No. Wells (Expanding Authorities),	0.017	0.069	.047**	0.012	.049**	0.012	.049*	0.009
N (9 Authorities)	89		89		89		89	
F	3.22**		46.67**		51.87**		117.6**	
Pseudo R^2	0.30		0.47		0.51		0.95	
No. Wells (Contracting Authorities)	−0.031	0.046	.012*	0.0049	.0081*	0.0040	−0.00021	0.0032
N (55–60 Authorities)	626		587		626		626	
F	1.76*		21.58**		24.31**		97.97**	
Pseudo R^2	0.04		0.44		0.48		0.88	

Note: ***p* < 0.01, **p* < 0.05, #*p* < 0.10 significance (two-tailed).
[a] Coefficients are adjusted for *Males 16–24*, *Population Density*, *Job Density*, *Unemployment*, *Income* and *Year* (b and SE not shown).

Table C2
Post-Hoc Fixed-Effects Regression Coefficients (b) and Robust Standard Errors (SE) for Process, Plant and Machine Operatives Employment on Crime Rates, 2004 to 2015 [a].

	Homicide		*Violence*		*Violent Crime*		*Property Crime*	
	b	SE	*b*	SE	*b*	SE	*b*	SE
No. Wells	−0.057	0.034	.020*	0.0085	.016*	0.0077	0.0082	0.0084
Process, Plant & Machine Employment	0.0058	0.0072	0.0012	0.0065	0.00041	0.0060	−0.0024	0.0042
N	745		709		745		745	
F	2.07**		26.1**		25.85**		89.79**	
Pseudo R^2	0.09		0.46		0.51		0.88	

Note: ***p* < 0.01, **p* < 0.05, two-tailed.
[a] Coefficients are adjusted for *Males 16–24*, *Population Density*, *Job Density*, *Unemployment*, *Income* and *Year* (b and SE not shown).

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