FRACCIDENTS: THE OSTENSIBLE LINK BETWEEN OIL AND GAS DEVELOPMENT AND CAR ACCIDENTS IN POST-SHALE BOOM TEXAS COUNTIES

by
Richard Benitez

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Abstract

New developments in the exploration of unconventional Oil and Gas (O&G) resources have become an energy industry trend. Nevertheless, there are underlying environmental and socio-economic impacts attributed to "fracking", which could strain public resources and local transportation networks. From 2012 to 2016, a quarter-fold increase in the number of producing wells occurred simultaneously with a 29 percent increase in total car crashes as well. This study explores the purported link between O&G development and car crashes using Texas county-level panel data. Despite this anticipated relationship, the results presented a tenuous relationship between the two. However, the overall magnitude of the relationship between O&G development and car crashes improves upon the existing literature. The research also maintains that there is still an emerging opportunity for future scholarship and policy formulation regarding O&G development and its residual impacts on public safety and quality of life among other communities of interest.

Keywords: oil and gas, public safety, transportation, energy

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Oil and Gas Development and the Shale Boom

Over the last few years there have been several key technical advances in oil and gas exploration and drilling, which have yielded unprecedented production numbers and profits for the petroleum industry. In the past, a simple vertical well that could produce approximately three million cubic feet of gas can now produce in the tens of millions today. Oil and gas (O&G) operators have leveraged hydraulic fracturing techniques to achieve increased levels of production: fracking a well entails using high pressure to pump water, proprietary sand, and myriad chemicals down a well into subsurface hydrocarbon reservoirs (i.e., shale deposits). This process "fractures" the earth and makes new perforations through which this mixture can flow into and allow hydrocarbons to the surface where they are separated and contained for storage and transport to refineries and other points of the energy network. Fracking is not only used on new wells but on existing wells too. This means that previously abandoned or *orphaned* wells are now being reentered by O&G companies with the aim of recapitalizing on their initial investments. While fracking has been around since the 1940s it was only until it was combined with horizontal drilling during that the "Shale Revolution" began in earnest—high energy prices spurred industry innovation and led to high employment numbers from 2005-2011. Some of the greatest benefits from the Shale boom were observed in Texas, a historically O&G-centric state. However, the flood in fossil fuels also created an industry bust that caused many O&G operators to go bankrupt and leave their once profitable investments behind.

Despite this boom-bust period between 2010 and 2015, U.S. oil production grew once again based on unprecedented global demand for petroleum, which stabilized oil prices. O&G companies face a lot of pressure to cut costs and increase profitability so "fracking"

has become even further used by operators. As such, companies are imposing "intense local impacts" during the drilling lifecycle and there are potentially intermediate and longer-term impacts because of the "widespread industrialization that accompanies contemporary hydraulic fracturing" (12).[1] Fracking involves a significant amount of water and sand that must be trucked in frequently to keep up with the feverish tempo of drilling operations especially early on. Moreover, drilling sites are chosen based on several factors such as proximity to O&G infrastructure, political considerations, and topographic/geological conditions; these locations are often times spread far apart from each other resulting in a high number of trips by commercial vehicles and drilling personnel moving back and forth. Frequent truckloads coming and going from the well site damage state and local roads that normally do not bear high volumes of traffic; these commercial vehicles encounter normal commuter traffic and interact with civilian drivers as well with perhaps dangerous outcomes. Thus, the potential link between O&G development and motor vehicle accidents among local communities is worth further research, specifically in Texas' top-producing counties.

Once a prospective site is developed there is a rush to extract as much oil and gas as possible within a brief window of time since a well's rate of production can decline quickly after the first few months. Consequently, there is a rush of heavy equipment and materials to these drilling operations that are usually sited in rural areas. It is very common for workers to commute long distances. Relatedly, these workers may be at a higher risk of being involved in a car accident as a result of the number of miles driven. Moreover, other drivers in the existing communities could be caught in the middle of increasing traffic congestion perhaps coming into conflict with oil and gas drivers and related transportation routes.

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[1] Christopherson, Susan, and Ned Rightor. "How Shale Gas Extraction Affects Drilling Localities: Lessons for Regional and City Policy Makers." *Journal of Town and City Management* 2, no. 4 (2012): 1-20.

Oil and Gas Literature Review

Within the current body of literature related to oil and gas development recent advances in drilling technologies such as horizontal drilling and hydraulic fracturing (i.e., "fracking") are characterized as having enhanced the extraction of hydrocarbons in unprecedented ways.[2] Thus, oil and gas development has taken hold in several "unconventional" areas in the United States, which has resulted in an "increased awareness for possible environmental consequences" (864).[3] In general, oil and gas drilling started in the 19th and 20th centuries but over the past decade the use of these two aforementioned methods has spurred the industry to drill deeper into tight shale geologic formations thousands of feet below the surface. At first, the intent was to "increase production from conventional wells, but their use in the [Texas] Barnett Shale…showed that they could be the key to unlocking" other significant mineral deposits as well (2).[4] Hydraulic fracturing became a popular technique in the 1940s but is now an industry standard to "enhance the production of low permeability formations, especially unconventional reservoirs such as tight sands, coal beds, and deep shales" (4).[5] Consequently, fracking has received increased attention in light of issues tied to specific environmental issues such as water contamination, air pollution, and even unusual seismic activity.[6] Nonetheless, oil and gas development presses on in several areas of the world and in the U.S. most notably in the state of Texas.

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[2] Vengosh, Avner, Nathaniel Warner, Rob Jackson, and Tom Darrah. "The Effects of Shale Gas Exploration and Hydraulic Fracturing on the Quality of Water Resources in the United States." *Procedia Earth and Planetary Science* 7 (2013): 863-66.

[3] Vengosh et. al. "The Effects of Shale Gas Exploration." 864.

[4] Zoback, Mark, Saya Kitasei, and Brad Copithorne. *Addressing the Environmental Risks from Shale Gas Development*. Vol. 21: Worldwatch Institute Washington, DC, 2010.

[5] Zoback et. al. *Addressing the Environmental Risks*. 1-18.

[6] Ibid. 7.

Zoback rightfully points out that oil and gas drilling operations require significant above-ground development, such as for example roads and other related transportation infrastructure; moreover, when a well is drilled the workers are "working around the clock for several weeks" (12-13).[7] Intuitively, this has the potential to not only put a general strain on public infrastructure and resources but also have an acute impact on public safety and local traffic patterns. Notably, authors McDermott-Levy, Ruth, Nina Kaktins, and Barbara Sattler point out that past analyses from the Department of Labor and Centers for Disease Control and Prevention evidence "a correlation between drilling activity and the number of occupational injuries related of drilling and motor vehicle accidents" (48).[8] This is in addition to the broad environmental issues already noted. Nonetheless, fracking is being aggressively implemented in at least 11 U.S. states and being considered for initial use in another eight.[9]

Within the exiting literature, the novel developments in oil and gas drilling are typically observed as occurring at the beginning of the 21st century with the "shale gas boom" where the number of wells tied to fracking was around 11,000 per year (8307).[10] A relevant review of the issue explored the main sources, hazards, and community health effects associated with unconventional oil and gas development but still noted that "relatively little peer-reviewed public health research exists" on the subject despite the increased pervasiveness of the situation at hand.[11] Within this journal article, the occupational health and safety of oil and gas workers was also explored—based on

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[7] Zoback et. al. *Addressing the Environmental Risks*. 1-18.

[8] McDermott-Levy, Ruth, Nina Kaktins, and Barbara Sattler. "Fracking, the Environment, and Health." *AJN The American Journal of Nursing* 113, no. 6 (2013): 45-51.

[9] McDermott-Levy, Ruth, Nina Kaktins, and Barbara Sattler. "Fracking." 46.

[10] Adgate, John L, Bernard D Goldstein, and Lisa M McKenzie. "Potential Public Health Hazards, Exposures and Health Effects from Unconventional Natural Gas Development." *Environmental science & technology* 48, no. 15 (2014): 8307-20.

[11] Adgate, John L, Bernard D Goldstein, and Lisa M McKenzie. "Potential Public Health Hazards." 8307.

secondary data from the U.S. Bureau of Labor Statistics (BLS) the fatality rate for these workers was more than eight times higher than other occupations and nearly one third of all deaths were a result of traffic accidents (8309).[12] The underlying link between oil and gas development and motor vehicle accidents in the surrounding communities is teased out in this article, to wit:

> Reports to state agencies indicate that traffic and industrial accidents occur in the course of [oil and gas] development and operations. Increased truck traffic in residential areas raises the likelihood for traffic accidents…The average multistage well can require hundreds to more than a 1000 truck round trips to deliver equipment (e.g., bulldozers, graders, pipe), chemicals, sand, and water needed for well development and fracturing (8311).[13]

The characterization of fracking operations relying on a fleet of trucks is both well documented and well understood. Some O&G operators have since decided to construct support infrastructure such as water pipelines to carry needed water back and forth to the well site.[14] However, this is atypical of the majority of oil and gas operators and most of them still rely on commercial trucks and trailers to support their wells to the detriment of regional and local traffic. As such, the truck traffic required to develop oil and gas wells and the expansion of related energy infrastructure has perhaps introduced a conflict between land use and the environment and at the least resulted in damaged roads and increased traffic delays in these areas. [15] While state and local government have pressed oil and gas operators to repair road damage; problems of traffic congestion remain a public concern. These issues become more pernicious as energy development expands into both suburban and urban areas from traditional rural areas.

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[12] Adgate, John L, Bernard D Goldstein, and Lisa M McKenzie. "Potential Public Health Hazards." 8309.

[13] Ibid. 8311.

[14] Brown, Stuart F. "Shale Energy Development Trends and Utilization." *Tribology & Lubrication Technology* 72, no. 4 (04// 2016): 26-30.

[15] Wiseman, Hannah J. "Urban Energy." *Fordham Urban Law Journal* 40, no. 5 (2013): 1793-833.

Nonetheless, a significant amount of literature on oil and gas development and fracking has centered around broad environmental issues such as air and water quality. Some research, however, has keyed in on the short-term and long-term economic impacts of hydraulic fracturing and the associated "boom or bust" nature of drilling.[16] Notably, the researchers characterized the speed of oil and gas development in the following way:

> The more oil and/or gas that you can make up front the better the economics…Individual counties and municipalities within the region are likely to experience accelerated boom and bust cycles, while the region as a whole is industrialised to support continued drilling, storage, and transportation of natural gas (7-8).[17]

Thus, the temporal environmental and economic impacts begin to manifest as early as in the intermediate term by affecting communities such as through increased commercial traffic and the sprawling industrialization of communities. Therefore, the link between oil and gas development and motor vehicle accidents becomes quite salient on first glance.

Within the Christopherson and Rightor article, another socioeconomic impact study focusing on O&G development in West Virginia identified an increase in the number of traffic accidents, emergency room visits, and demand for emergency response services over a six-year period.[18] Another working paper focused on the Pennsylvania-New York Marcellus shale region, which highlighted the fact that "dust, noise, and road damage from industry truck travel are tops" on the list of citizen complaints in areas where shale gas is extracted via shale gas drilling (1-2).[19] Also, Randall noted that oil and gas tanker trucks used in the transportation of water or hydrocarbon product were regularly running loads past legal

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[16] Christopherson, Susan, and Ned Rightor. "How Shale Gas Extraction Affects Drilling Localities." 1-20.

[17] Ibid. 7-8.

[18] Ibid. 10.

[19] Randall, CJ. "Hammer Down: A Guide to Protecting Local Roads Impacted by Shale Gas Drilling." Working Paper Series for A Comprehensive Economic Impact Analysis of Natural Gas Extraction in the Marcellus Shale, Cornell University Department of City and Regional Planning, available at: http://greenchoices. cornell. edu/development/marcellus/policy. cfm (accessed 2nd July, 2011), 2010.

weight limits.[20] Not long after, a Texas A&M University System technical report, sponsored by the Texas Department of Transportation (TxDOT), was commissioned to assess the impact of increased energy related activities on Texas highways and roads.[21] The 2012 report noted an increase in the number of oil and gas permits issues in the mid-2000s; subsequent new oil and gas development resulted in an increase in truck traffic in the north Texas Barnet shale area where on average for a single well, an estimated:

- 187 truckloads for pad site preparation, rig mobilization, drilling operations, and rig removal;
- 997 truckloads for hydraulic fracturing operations;
- 88 truckloads per year for maintenance; and
- 997 truckloads every few years for refracking (5).[22]

In the Barnett shale region alone, the researchers, using both TxDOT and Texas Department of Public Safety (TxDPS) data, reported that oil and gas trucks had frequent load issues, ran over traffic signs, damaged roads, and increased traffic congestion (5).[23] Moreover, the researchers observed firsthand safety issues such as truck drivers making illegal turns and the prevalence of obscured intersections and driveways limiting driver visibility.[24] In this study, the researchers focused in on the impact of energy-related development on roadway operations and safety via two discrete analyses: the first analysis focused on crash rates occurring in three TxDOT districts, comprising of around 9-17 counties; the second analysis dived into commercial vehicle enforcement data from TxDPS.[25] The researchers were unable to conclude that energy developments were

[20] Randall, CJ. "Hammer Down." 12.

[21] Quiroga, César Augusto, Emanuel Fernando, and Jeongho Oh. "Energy Developments and the Transportation Infrastructure in Texas: Impacts and Strategies." Texas Transportation Institute, Texas A & M University System, 2012.

[22] Quiroga, César Augusto, Emanuel Fernando, and Jeongho Oh. "Energy Developments." 5.

[23] Ibid. 5.

[24] Ibid. 39.

[25] Ibid. 107.

responsible for higher crates along roadways of interest because of "the existing data do not include any data elements connecting energy developments with crashes" but did not rule out the plausibility that higher traffic volumes could result in a higher crash rates—traffic corridors where energy developments take place, at least circumstantially, have higher crash rates.[26] The technical report hints at leveraging data from the Railroad Commission of Texas (RRC) and their extensive oil and gas well permit database that also includes spatial data (locations of wells) to supplement more descriptive non-spatial data (well status, well type, well completion date, etc.). The Quiroga et. al. study was later identified within other related research tied to assessing roadway damage from oil and gas development albeit in reference to the Marcellus shale in Pennsylvania.[27] This study reiterated the theoretical negative impact O&G development and fracking have on traffic but did not expand its focus past infrastructure costs and impacts to public safety.

Other studies begin to focus on oil and gas employee health, risk, and exposure factors and fatal motor vehicle crashes because of the "frequent travel between well sites…and long and irregular hours of work that contribute to driver fatigue" (168).[28] The researchers highlighted the time period of 2003 through 2009 as their subject interest and noted that motor vehicle related fatalities were the leading cause of death, 28 percent, among oil and gas extraction workers (169).[29] When compared to other major industry groups this is second highest as well with a rate of 7.6 workers per 100,000; the researchers highlighted the following key findings as well:

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[26] Quiroga, César Augusto, Emanuel Fernando, and Jeongho Oh. "Energy Developments." 107.

[27] Abramzon, Shmuel, Constantine Samaras, Aimee Curtright, Aviva Litovitz, and Nicholas Burger. "Estimating the Consumptive Use Costs of Shale Natural Gas Extraction on Pennsylvania Roadways." *Journal of Infrastructure Systems* 20, no. 3 (2014): 06014001.

[28] Retzer, Kyla D, Ryan D Hill, and Stephanie G Pratt. "Motor Vehicle Fatalities among Oil and Gas Extraction Workers." *Accident Analysis & Prevention* 51 (2013): 168-74.

[29] Retzer, Kyla D, Ryan D Hill, and Stephanie G Pratt. "Motor Vehicle Fatalities." 169.

> Pickup trucks were the most common type of vehicle occupied by the decedent (51.5%), followed by semi-trucks (26.7%)…Over half (n = 113, 55.9%) of oil and gas extraction worker fatalities were the result of non-collision incidents.[30]

The main takeaway from the Retzer et. al. study was the clear need for better protection of oil and gas workers and increased awareness of these risks and exposure factors for the energy industry overall.

In a later study, the effect that increased truck traffic from shale gas development on motor vehicle accidents was finally explored—the researcher's primary aim was to compare traffic accidents rates between counties with high levels of drilling activity to counties with no drilling activity.[31] Yet again the area of interest was the Marcellus shale region in Pennsylvania, however, within the 2010-2012 period. This study found that drilling counties exhibited up to 23 percent higher rates of vehicle crashed during the three-year period and 61-65 percent higher rates of heavy truck crashes at least in the 2010-2011 timeframe.[32] Moreover, accident rates in those counties during months when drilling occurred compared to non-drilling months showed that drilling was associated with more modest effects on accident rates: a 5% increase in vehicle crash rates and a 23% increase in heavy truck crash rates.[33] Nevertheless, there were differing results among Pennsylvania counties when grouped by region—southwestern counties did not experience significantly higher rates of crashes for either motor vehicles or trucks in contrast to the aforementioned northern counties; the researchers were unable to explain for these differences between north and south counties but speculated that accident rates might spike once a certain threshold

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[30] Retzer, Kyla D, Ryan D Hill, and Stephanie G Pratt. "Motor Vehicle Fatalities." 170.

[31] Graham, Jove, Jennifer Irving, Xiaoqin Tang, Stephen Sellers, Joshua Crisp, Daniel Horwitz, Lucija Muehlenbachs, Alan Krupnick, and David Carey. "Increased Traffic Accident Rates Associated with Shale Gas Drilling in Pennsylvania." *Accident Analysis & Prevention* 74 (2015): 203-09.

[32] Graham, Jove, Jennifer Irving, Xiaoqin Tang, Stephen Sellers, Joshua Crisp, Daniel Horwitz, Lucija Muehlenbachs, Alan Krupnick, and David Carey. "Increased Traffic Accident Rates." 207.

[33] Ibid. 207.

number of wells drilled has been reached.[34] The final word from the researchers was a desire that their study fills an "existing gap in the literature regarding impacts of a rapid expansion of [oil and gas development] on public health issues other than environmental impacts" (207).[35]

Only until recently did researchers begin to focus in earnest on Texas oil and gas development and the link between transportation-related impacts; one of these areas is the Eagle Ford shale region (south Texas), which is experiencing heavy truck traffic because of its confirmed oil, gas, and condensate reserves has been "revolutionized" due to fracking (82).[36] The researchers leveraged crash data from TxDOT and analyzed the 15 top producing counties, out of 21 in the Eagle Ford region, seeking to create an area of focus from which a baseline on the number of traffic crashes prior to the fracking boom (pre-2008). The study then proceeded into the creation of two discrete surveys that were distributed to local government officials within the 15-county sample. These survey responses coalesced into community perceptions and suggested that respondent counties are "experiencing significant challenges in meeting the increased demands placed on their transportation system by the increases in fracking development" (92).[37] The purported negative impacts tied to fracking such as damaged traffic infrastructure (highways, roads, bridges), increased traffic, and increased motor vehicle accidents were all confirmed by the researchers.

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[34] Graham, Jove, Jennifer Irving, Xiaoqin Tang, Stephen Sellers, Joshua Crisp, Daniel Horwitz, Lucija Muehlenbachs, Alan Krupnick, and David Carey. "Increased Traffic Accident Rates." 207.

[35] Ibid. 207.

[36] Rahm, Dianne, Billy Fields, and Jayce L Farmer. "Transportation Impacts of Fracking in the Eagle Ford Shale Development in Rural South Texas: Perceptions of Local Government Officials." *Journal of Rural and Community Development* 10, no. 2 (2015).

[37] Rahm, Dianne, Billy Fields, and Jayce L Farmer. "Transportation Impacts of Fracking." 92.

Data and Methods

The majority of oil and gas (O&G) related well data was acquired from the Railroad Commission of Texas (RRC)[38]—the oldest regulatory agency in the state and the nation. This data provides our independent variable of producing wells *(pro)* along with other data such as shut-in wells (abandoned or orphaned, i.e., inactive) and injection wells (typical of a fracking operation). The O&G well data was supplemented by motor vehicle crash and crash fatalities from the Texas Department of Transportation (TxDOT) and their Crash Data Analysis and Statistics Annual Summary Reports[39]. Additionally, population data was retrieved from the Texas Department of State Health Services (DSHS)[40]. Lastly, county specific data that designated Texas our sample counties as either rural or metropolitan in development was obtained from the Texas Department of Agriculture (TDA)[41]. Of special interest were top-oil and gas producing Texas counties, which are assumed to be located along the three-regional shale plays in Texas: the Eagle Ford (Southern Texas); the Barnett (Middle Texas); and the Permian/Delaware basin (Western Texas)[42], which are largely confined to Texas—other significant shale plays such as the Woodford (North Texas) and Haynesville (East Texas) were excluded because most of their respective area lies outside Texas, see *Figure 1 Lower 48 States Shale Plays Selected Area (EIA, 2016).*

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[38] Railroad Commission of Texas. "Well Distribution by County - Well Counts." RRC.state.tx.us. http://www.rrc.state.tx.us/oil-gas/research-and statistics/well-information/well-distribution-by-county-well-counts (accessed October 13, 2017).

[39] Texas Department of Transportation. "Texas Motor Vehicle Crash Statistics." TxDOT.gov. https://www.txdot.gov/government/enforcement/annual-summary.html (accessed October 13, 2017).

[40] Texas Department Health and Human Services. "Population Data for Texas." DSHS.texas.gov. https://www.dshs.texas.gov/chs/popdat/default.shtm (accessed October 13, 2017).

[41] Texas Department of Agriculture. "Texas County Designations." Texas.agriculture.gov. https://www.texasagriculture.gov/Portals/0/forms/ER/Rural-Metro%20Counties.pdf (accessed October 13, 2017).

[42] United States Energy Information Agency. "Shale gas and oil plays, Lower 48 States (6/30/2016)." EIA.gov/maps. https://www.eia.gov/maps/maps.htm (accessed October 13, 2017).

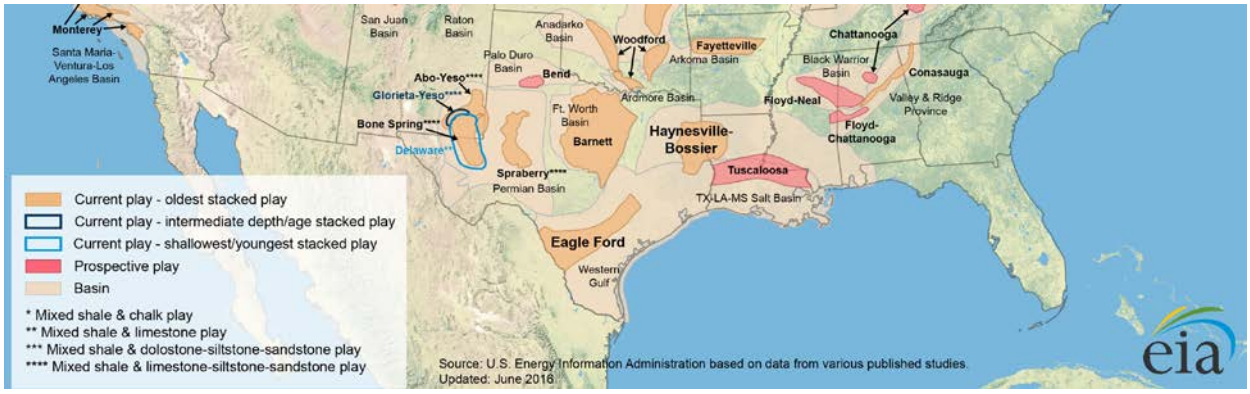

Figure 1 Lower 48 States Shale Plays Selected Area (EIA, 2016)

The RRC has organized the administration of O&G permitting and oversight into districts of which the research focused on five individual districts that span across 166 counties: San Antonio and Corpus Christi (Eagle Ford basin); Abilene and Kilgore (Barnett basin); and Midland (Permian/Delaware basin). These districts are characterized as mostly rural in nature like the largest districts Abilene (75 percent) and Midland (88 percent). Altogether, there has been about a quarter-fold increase in producing wells from 2012 to 2016. The most significant activity was observed in San Antonio (58 percent rural) and Midland districts. Moreover, there has been an across the board decrease in shut-in wells (38 percent) and a parallel increase in injection wells (15 percent).

Table 1 Texas County Producing Wells by Selected District in 2012 and 2016

Districts	Counties	Pro. Wells 2012	Pro. Wells 2016	%Change Pro. Wells '12, '16
Abilene	24	10,362	10,571	2%
Corpus Christi	15	1,593	1,479	-7%
Kilgore	46	10,565	10,561	0%
Midland	41	69,417	84,350	22%
San Antonio	40	18,709	26,460	41%
Total	**166**	**110,646**	**133,421**	**21%**

Data from the Railroad Commission of Texas (RRC), September 2012 and September 2016.

Results

Turning to motor vehicle accidents, when analyzing the raw counts there was an overall 29 percent increase in the number of motor vehicle crashes from the 2012 to 2016-time period. Our panel data spanning the years 2012 and 2016 is "strongly balanced" covering the beginning of the shale boom in Texas and leveraging the most recent and complete annual crash data. Further research can benefit from leveraging 2017 data once available. The data were entered into Stata, dependent variable was motor vehicle crashes, and the collected observed panel data (n=332) yielded the following based on our independent variables for well type (production, shut-in, injection, population) while controlling for county designation (rural vs urban), and both time and entity effects:

Table 2 The Effect of Oil and Gas Development on Motor Vehicle Accidents (2012, 2016)

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Production Wells	**-.27** **(.12)**	-.18 (.12)	.04 (.08)	-.12 (.16)	.14 (.09)	-.12 (.11)
Shut-in Wells	-	1.42 (1.6)	1.47 (1.23)	1.95 (1.94)	1.99 (1.33)	1.95 (1.36)
Injection Wells	-	-.44 (.34)	**-.66*** **(.34)**	4.92 (.92)	4.88 (3.77)	4.92 (3.75)
Population	-	-	**.01*** **(.00)**	**.06*** **(.02)**	**.06*** **(.01)**	**.06*** **(.01)**
Rural or Geographic Dummies (County or District)	-	-	303.03 (217.33)	**2207.99**** **(989.34)**	Omitted	Omitted
Constant	2058.57 (538.77)	1837.51 (466.17)	-502.97 (298.91)	-3274.60 (1397.51)	-6428.92 (1985.48)	-6528.00 (2101.49)
Entity Random Effects	No	No	No	Yes	No	No
Time Random Effects	No	No	No	Yes	No	No
Entity Fixed Effects	No	No	No	No	Yes	No
Time Fixed Effects	No	No	No	No	No	Yes

Notes: Motor vehicle crashes are measured using the variable *crash*. Robust standard errors, clustered on *county*, are given in parentheses under the estimated coefficients. * $p < .1$, ** $p < .05$, *** $p < .01$.

Our panel data spanning 2012 and 2016 is "strongly balanced" covering the beginning of the shale boom in Texas and leveraging the most recent and complete annual crash data. Further research can benefit from leveraging 2017 data once available. The results demonstrate a mixed picture regarding the overall effect of O&G development on the number of motor vehicle accidents. In Model 1, production wells have a slight negative effect on motor vehicle accidents, this result is significant at the 95% confidence interval; however, across other models that leverage other variables, the independent variable has a less than significant impact on car crashes across our sample of Texas counties. Subsequent models include other variables such as shut-in wells and injection wells while also controlling for population, rural makeup, and entity and time effects (random and fixed).

Model 3 for example, shows that our injection variables wells also has a slight negative impact on the number of motor vehicle accidents while population has a low magnitude but high significance of impact on car crashes. Altogether, the panel data allows the research to control for unobserved variables (i.e., limiting OVB) and variables that change over time but not across entities. Counties and Districts with significant drilling activity (production, and injection) most likely have steady upward flows of drilling over time and drilling counties continue to be such because of the stable location of the selected shale plays. In Model 4, random effects across entities and time were included—where the coefficients on shut-in and injection wells were of higher magnitude yet lacked statistical significance. Differences across entities were controlled for by including population and development-type (rural vs. metropolitan) and both had statistically significant relationships on the dependent variable. In Models 5 and 6 the research respectively used entity and time fixed effects—these models remove the effect of time-invariant characteristics (development type, county or district) and demonstrated higher magnitude coefficients for shut-in and

injection wells but lacked a notable statistical significance while the population variable again proved to have a strong statistical impact on motor vehicle crashes.

Turning to commercial motor vehicle accidents, when analyzing the raw counts there was also an overall 24 percent increase during the same time period. Further research can also leverage 2017 data once available. The data were entered into Stata, dependent variable was commercial motor vehicle crashes, and the collected observed panel data (n=332) yielded the following based on our independent variables for well type (production, shut-in, injection, population) while controlling for county designation (rural vs urban), but favoring entity effects:

Table 3 The Effect of Oil and Gas Development on Commercial Motor Vehicle Accidents (2012, 2016)

Variable	Model 1	Model 2	Model 3	Model 4
Production Wells	**-.01** **(.00)**	**-.01** **(.00)**	.00 (.00)	**-.02** **(.00)**
Shut-in Wells	-	1.42 (1.6)	.07 (.04)	.06 (.06)
Injection Wells	-	-.00 (.02)	-.02 (.01)	.16 (.17)
Population	-	-	**.00*** **(.00)**	**.00*** **(.00)**
Rural or Geographic Dummies (County or District)	-	-	**47.01**** **(23.90)**	Omitted
Constant	133.46 (32.10)	120.87 (29.81)	-41.70 (25.88)	-279.35 (101.38)
Entity Random Effects	No	No	Yes	No
Time Random Effects	No	No	Yes	No
Entity Fixed Effects	No	No	No	Yes
Time Fixed Effects	No	No	No	No

Notes: Commercial motor vehicle crashes are measured using the variable *cmvc*. Robust standard errors, clustered on *county*, are given in parentheses under the estimated coefficients. * $p < .1$, ** $p < .05$, *** $p < .01$.

The resultant data was analyzed across four models all evidencing negligible significance. In Model 1, production wells have a very slight negative effect on motor vehicle accidents, this

result is significant at the 95% confidence interval; across other models the independent variable has approximately the same significance and level impact on commercial motor vehicle accidents across our sample of Texas counties. Subsequent models also include other variables such as shut-in wells and injection wells and control for population, rural makeup, and entity and time effects (random and fixed). Model 3 for example, shows that all well types, when taking population and rural makeup into account, have no significant impact on commercial vehicle accidents; the population variable again proved to have a strong statistical impact here too. In Model 4, entity fixed effects were included and demonstrated a less than significant negative relationship between production wells and commercial car accidents at the 95% confidence interval.

A note about the data related to oil and gas production statistics: the RRC maintains *Historical* and *Monthly Production* data by District and Field in some cases stretching all the way back to 1935. Production data was leveraged from the RRC's *Production Data Query* (PDQ) system where information reported by the Commission is taken directly from reports submitted to the RRC by O&G operators. There is a two-month lag on production data as well. That said, the database itself is continuously updated, at least monthly, to correct data to account for revisions or delinquent reports from O&G operators. Over the course of the research and data collection phase there were several instances of counties being omitted or identified incorrectly as belonging to another district. There were also some cases of duplicate entries for a county and discrepancies in production data were noted as well. At the very least, the research seeks to encourage the RRC and other interested stakeholders to advocate for more rigorous cleanup and quality control of the data for the future. The dynamic of self-reporting on production data may merit some enhanced scrutiny as well on the part of the RRC as well.

Conclusion and Discussion

This research set out to highlight the potential link between oil and gas (O&G) development and motor vehicle accidents. Moreover, the link between O&G activity and commercial vehicle accidents was also explored to supplement the context of this relationship too. The area of reference was Texas' top producing counties. This subject area was deemed appropriate because of the increase in O&G activity Texas-wide but most acutely observed on a county level corresponding to their proximity to subsurface shale plays of the Barnett, Eagle Ford, and Permian. Their location made them an interesting sample because of the time period of reference as well: 2012-the beginning of the U.S. shale boom through the year 2016, which is when most recent data was available across all sources. Our findings demonstrate, however, that there is no significant link between increasing energy development and increasing rates of motor vehicle accidents in Texas' top-producing counties from 2012 to 2016.

The Barnett (Southern Texas) shale spans over 18 counties in RRC Districts 5, 7B and 9; the Eagle Ford (Eastern Texas) covers Districts 1-6; and the Permian (West Texas) covers districts 7C, 08, and 8A. The recent developments in O&G technologies were mostly observed in the Permian and collectively these regional shale plays have driven increased production numbers and newfound American energy self-sufficiency. This is in contrast to decades of anxiousness tied to the rising energy prices because of a lack of supply and access to resources. Nevertheless, the research posited that a rush towards developing new oil and gas deposits would result in uneven urban development and produce secondary public health and safety impacts in the form of increased motor vehicle accidents through negative traffic impacts. While there has indeed been an increase in both, O&G production and car accidents, in Texas' top-producing counties it appears they are not linked to each other.

There are indeed other factors at play that fall outside of the scope of the research for the moment but future parties can develop these relationships further on later.

There is a reported lack of focus on the overall health of the national transportation infrastructure of which O&G operators greatly depend on to transport their bounty to refineries and shipping ports. At numerous well sites, workers are tasked with transiting to and from in the early stages and well after production begins. Perhaps operators are reasonable and prudent enough to work with community partners to ensure appropriate maintenance and construction is undertaken throughout to maintain good roads, bridges, and the associated traffic infrastructure, which is also enjoyed by other citizens in the community as a common good. This has the impact of reducing the number of accidents involving O&G personnel on the job and in general mitigating the negative traffic impacts that may accompany energy development. It is well-known that O&G development can bring jobs to communities, which results in a larger tax base for government to tap into for capital improvements and infrastructure maintenance projects. That said, there is still a lingering concern relative to the "boom-bust" cycles that are associated with energy development. Further research on this topic should be commissioned to better understand these short and long-term impacts in order to make better decisions on where and how to develop energy resources while keeping local communities in mind.

Fracking has been at the vanguard of the "Shale Revolution" and should still be judiciously debated because of the requirement for increased truckloads of equipment and water resources. This results in not only an increase in overall traffic but specifically commercial vehicle traffic; which can lead to accelerated infrastructure degradation (i.e., highways, roads, bridges, etc.) and impact public safety via influencing the frequency of car

crashes. Local communities should still look to balance short term economic gains vis-à-vis long term secondary impacts through several means such as regulating truck traffic to predetermined routes and ensuring O&G operators pay their own way and take up their share of the burden. In some instances, operators have acquiesced to local government's requests to share, in advance, traffic impact data with information such as: prospective truck routes, estimated weights and cargo manifests; and carry insurance bonds that mitigate any damages caused along the life of the well's operation.

These aforementioned prescriptions are precautions to take in areas who have a long history of energy development, like Texas counties for example, and other areas contemplating energy industry expansion as well. It is not unreasonable for local government to ask incoming O&G operators for a "transportation plan" in exchange for a drilling permit or even reentry into an abandoned/orphaned well—this plan could include: the estimated number of truckloads or site vehicles, the expected times or schedule of operations and transport, and planned motor vehicle safety trainings or current training record of identified transport drivers. These hypothetical traffic/transportation impact plans could be compared to existing studies tied to existing environmental requirements and policies that are already required by new local government ahead of new industrialization or capital asset construction (e.g., National Environmental Policy Act [NEPA] environmental assessments [EA], and environmental impact studies [EIS], or other exemptions and the like). Further, it probably is not unreasonable either to encourage operators to pay into infrastructure, transportation improvement pools/funds or even public safety funds through impact fees based on the fact that if O&G development continues to increase and expand at current rates future issues might arise that could curtail growth. Otherwise, governments at local, regional, and state levels might be faced with funding shortfalls later thereby delaying the

routine maintenance of traffic infrastructure and create deferred maintenance backlogs, which could increase the probability of unsafe road conditions writ large.

Local governments would do well to think first of the long-term picture relative to potential short-term gains of O&G development. The energy industry is still beholden to market shifts and other overarching dynamics because the market for energy is global. However, fracking operations and their impacts are local. Therefore, decisions on where to drill and how to support related drilling activity can have important consequences for local communities at town, city, and county levels. In the case of Texas, large swaths of the state are faced with the reality of continuous drilling activity alongside urbanization and other demographic shifts as well. The lines dividing drilling activities and where people live, work, and play are bumping up against each other or in some instances are quite blurred. Thus, it is important to better understand the relationships between the two; considering the link between O&G development and motor vehicle accidents is just one of those relationships worthy of continued interest and expanded inquiry well past this research.

This research sought to build upon the current body of literature related to oil and gas development and its associated drilling technologies such as fracking; this research supplements the significant amount of literature on energy-specific environmental issues such as air and water quality. As such, the underlying effect that increased truck traffic from energy, namely shale oil and gas, development on motor vehicle accidents was explored herein. There is still opportunity to drill down further and separate oil and gas activity from one another to perhaps uncover hidden relationships between them and the frequency of motor vehicle accidents. Moreover, within crash data there could still be potential for parsing commercial vehicle data to identify what incidents are directly tied to O&G development

and their respective personnel. Therefore, there is still a considerable amount of inquiry to be commissioned under this area of interest. Despite the research demonstrating no apparent link between O&G development and motor vehicle accidents in Texas' top producing counties other geographic areas of interest may illicit differing results. The supposed negative impacts tied to fracking may be exaggerated at the moment but might perhaps still be confirmed by future researchers if energy development is ill-planned and unconsidered by community leaders and other key stakeholders.

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