THE EFFECTS OF ORGANIZATIONAL, COMMUNITY, AND STATE REGULATORY CHARACTERISTICS ON TEXAS OIL AND GAS EXTRACTION FACILITY VENTING AND FLARING PRACTICES

A Dissertation

by

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ABSTRACT

Why do some companies release more methane than others? Using a mixed methods approach, I explore this question by analyzing variation in Texas oil and gas extraction facility venting and flaring practices. The methane emissions from oil and gas venting and flaring contribute to global climate change, making the practice a growing concern. Using an open systems organizational theory approach, I develop a conceptual model to explain how organizational power relates to methane emissions from venting and flaring by the oil and gas extraction industry. I test the conceptual model with several sources of data and analyses. First, I analyze archival information to show how, due to direct involvement of powerful oil and gas companies, policy changed to increase the legal opportunities for companies to vent or flare gas. Second, drawing upon quantitative environmental justice research methods, I create a geographic information system to examine how community inequality is related to environmental inequality. Third, I analyze a zero-inflated negative binomial regression model that demonstrates that extreme venting and flaring is associated with low poverty, less politically organized, and predominately Hispanic neighborhoods. Finally, I explore the effects of the organizational characteristics of facilities, the companies that directly own them, and the political legal environment in which they are embedded on the environmental efficiency of facility operations through a clustered two-part hurdle regression model. I find subsidiary organizations are more prone to pollution because there is a liability firewall that protects ultimate parent companies from possible social repercussions. Findings suggest political and organizational power are key factors contributing to the environmental decisions of organizations. By enacting new state policy, methane emissions could be reduced.

DEDICATION

I dedicate this project to my husband, Tai Willyard. He is my rock and the source of my hope, inspiration, perseverance, understanding, and love.

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All other work conducted for the dissertation was completed by the student independently.

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1. INTRODUCTION- A BURNING ISSUE: FLARING AND VENTING IN TEXAS

> "It doesn't have to be like this, but the excuses for flaring are all too familiar. The gas price is too low, pipelines are too expensive, upfront costs to use or convert the gas locally are too high. And the excuses will keep coming until we finally face reality: We cannot drill our way out of the coming climate crises… It is time to face the issues of air pollution and greenhouse gas emissions from oil and gas exploration. Too much time and energy, literally, have already been wasted." (Schade 2014)

Although air pollution in the United States has steadily declined over the last four decades, *rural* air pollution in the United States has been increasing over the same time period due to oil and gas industry flaring and venting practices. Venting and flaring is an often-unnecessary practice of the oil and gas extraction process. Natural gas and oil are produced on a construction area known as a drilling pad using one or more drilling rigs on top of one or more holes in the ground, known as wells. When oil and gas is extracted from a well, natural gas can be released or leaked into the air (a practice known as venting) or burned and released into the atmosphere using a flare stack (a practice known as flaring). While some venting and flaring practices are necessary during emergencies and accidents, routine venting and flaring practices are a choice by oil and gas companies. While routine venting and flaring is banned throughout most of Europe, in the United States routine venting and flaring is allowed in many states, including Texas.

In order to avoid routine flaring practices, companies must invest in green technologies and infrastructures. Even though natural gas has economic and use value, since it is a legal option, many companies choose to not build pipeline infrastructures or, when pipeline is otherwise unavailable, fail to rent or buy the equipment necessary to collect and store extracted natural gas until the pipeline is constructed or it is transported to consumers by other means, and instead dispose of the gas by venting or flaring. Venting and flaring is a growing concern because in addition to wasting a valuable, finite natural resource, it creates air pollution and emits greenhouse gasses that contribute to global climate change.

1.1 Common Explanations of Flaring and Venting

Although natural gas extracted along with oil and other petrochemicals at extraction sites has economic value, companies may directly choose to vent or flare for three primary reasons. First, it is common for operators to flare gas the first few days after drilling is completed in order to test the pressure and composition of extracted natural resources. However, some other companies choose to forgo this unnecessary waste and instead use portable green completion equipment. Second, since wells must go through a costly process to be shut-in[1], operators flare gas to maintain a safe pressure during emergencies and repairs. Third, out of perceived economic

[1] Shutting in a well is a process by which a well is plugged at a specified level and filled with concrete to prevent natural gas from escaping. Depending on the depth of the well, shut in costs can be anywhere from $569 - $527,829 (Joyce 2015).

interests and administrative costs, some companies choose to immediately vent and flare extracted natural gas, rather than invest in and build the infrastructure and technology necessary to effectively capture, store, and transport the gas to be sold on the market. While oil and gas extraction industry venting and flaring practices are often viewed as a natural part of the production process, I argue that there is a social component in both corporate choices to vent and flare and the normal accidents that lead to venting and flaring.

Figure 1. Gas Flare in Permian Basin

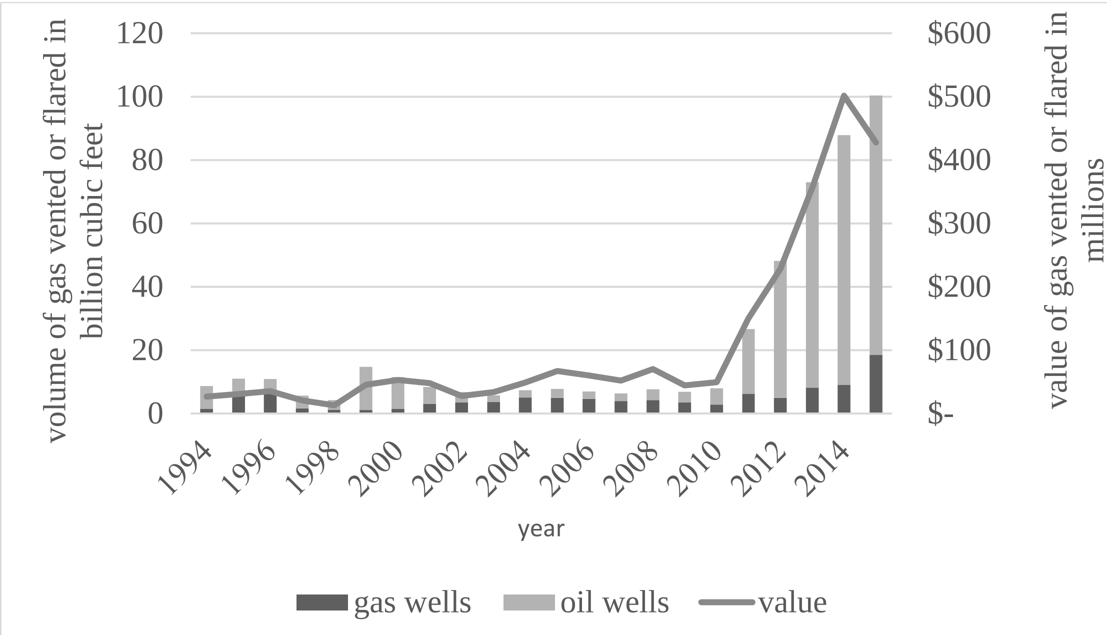
Source: Thornberrey, 2013 [Reprinted]

1.2 Modern Venting and Flaring Patterns in Texas

As fracking technologies have opened up oil and gas development in previously unreachable areas, the practice of venting and flaring has become a growing economic concern for states with finite oil and gas reserves. Prior to the beginning of the shale oil boom in 2005, the Energy Information Administration (2017) estimated 96,408 million cubic feet of natural gas worth nearly $836 million was flared or vented[2] at extraction sites across the United States; by 2015, the amount tripled to 289,545 million cubic feet worth over $1,233 million. A large amount of that gas has been increasingly flared in Texas, which is the largest producer of oil and gas in the United States. As described below (See *Figure 2*), while prior to the shale oil boom in 2005, the Texas Railroad Commission estimated 7,743 million cubic feet of natural gas worth nearly $57 million was wasted by flaring or venting at extraction sites in Texas; by 2015 the amount grew over tenfold to 100,388 million cubic feet worth over $427 million.

[2] Federal and state records do not differentiate between venting and flaring estimates.

Figure 2. Estimated Waste from Flaring and Venting in Texas



Source: Willyard, 2019 [Reprinted]

1.3 Importance of this Research

Flaring is problematic, as it wastes energy resources, creates health hazards and contributes to climate change. While urban air pollution in the United States has steadily declined, flaring has dramatically increased the number of toxic air pollutants in rural areas in Texas due to shale gas development. In 2012, flaring conducted in the Eagle Ford Shale, which is just one of Texas' many oil and gas shale plays, led to over 15,000 tons of pollutants being released into the atmosphere, which is more than all high-polluting Texas oil refineries combined (Tedesco and Hiller 2014). Flaring releases a large amount of air pollutants into the atmosphere including carbon dioxide, methane, and other volatile organic compounds such as benzene, ethlylbenzene and n-hexane. In fact, flaring is the largest industrial source of volatile organic compounds that produce smog and it is the largest source of methane emissions by the oil and gas industry (EPA 2017). The magnitude of methane emissions from flaring is particularly problematic because global climate change is a growing concern. According to the Environmental Protection Agency (EPA 2015), over the course of 100 years, methane contributes to climate change over 25 times as much as carbon dioxide. In short, there is ample research from atmospheric scientists that venting and flaring from the oil and gas industry has a negative impact on the surrounding natural environment.

While natural scientists continue to explore venting and flaring (Howarth, Santoro, and Ingraffea 2011. Buzcu-Guven, and Harriss 2012; O'Sullivan and Paltsev 2012; Elvidge, Zhizhin, Baugh, Hsu and Ghosh 2015), social scientists have yet to fully explore the phenomenon. The primary purpose of this research is to bring social organizations into the analysis of oil and gas industry venting and flaring practices. It is critical to include human organizations in climate change studies because most methane and carbon emissions are not the result of a natural phenomenon; they are the result of the purposeful, incidental, and accidental actions of man-made organizations. As such, the social organization is the primary unit of analysis. This study advances knowledge of how the characteristics of organizations and their interconnected external environment relate to extreme pollution by industrial facilities. I take an open systems political economy approach to organizational behavior, meaning I conceptualize organizational behavior as the result of the historical development of power structures, such as the informal norms and formal rules both within the organization and between organizations. I elaborate my theoretical framework below.

1.4 The Pathways to Pollution Framework

There are various institutional processes contributing to climate change. Sociological explanations of climate change can be broken down into three lines of research, based on the unit of analysis: global, national/local political, and organizational (Grant, Jorgenson, Longhofer 2018).

First, world systems analysis research shows that capitalist growth and industrialization have led to the establishment of global hierarchies supporting extreme pollution (Bunker 1984; Smith 1994; Wallerstein 2011). Partly through the vertical flow of exports from less powerful "peripheral" and "semi peripheral" nations to the most geopolitically powerful "core nations," core nations exploit the natural and economic resources of peripheral and semi peripheral nations, leading to a larger ecological footprint (Fitzgerald and Auerbach 2016; Hornborg 1998; Jorgenson 2006; Jorgenson 2011; Rice 2007). In other words, expansive pollution in modern society continues because core nations benefit from environmental exploitation while bearing few of the costs.

Second, from the national/local politics perspective, the advancement of anthropocentric climate change is the result of inequality within national political-regulatory systems (Prechel 2015), and among the political actors involved in environmental decision making (Mohai, Pellow and Roberts 2009; Pellow 2000). Facilities controlled by companies in states with stronger environmental policies are more likely to adhere to environmental norms and pollute less than facilities controlled by companies in states with weaker environmental policies (Prechel and Lui 2012). Additionally, a lack of inclusive community involvement in land use decisions leads to the development of extreme environmental risks, predominately in socially vulnerable communities (Bullard 1990). In short, when companies dominate local or national political processes, they face fewer costs to violating environmental norms. In turn, they pollute more.

Third, from the organizational perspective, the differences in corporate organizational power structures relate to extreme pollution (Grant et al. 2002; Grant, and Jones 2003; Grant and Jones 2004; Grant et al. 2010; Prechel 2015; Prechel and Istvan 2016; Prechel and Touché 2013; Prechel and Zheng 2012). This research finds large, complex, financially constrained organizations pollute the heaviest because they are subject to resource dependence (i.e., the degree to which an organization depends on their external environment to survive) and organizational inertia (i.e., the extent to which an organization resists change). Organizations with more power to resist change have more power to pollute.

In the process of identifying the global, political, and organizational factors contributing to climate change, social scientists have identified several combinations of structural determinates of disproportionate pollution by heavy polluting facilities, known as hyper-polluters. Rather than examining global, national, and organizational variables as competing predictors, recent research uses structural "causal recipes", or different combinations of variables that work together, to predict hyper-polluter emissions (Grant, Jorgenson, Longhofer 2018). Examining an international sample of the world's powerplants, research shows those with the highest emission rates are (Grant, Jorgenson, Longhofer 2018:65-66):

> "(a) located in the world-system's core zone and in nations that are disengaged from global environmental norms and lack a system of political checks and balances (coercive configurations), (b) located in the world-system's core zone and in nations that are disengaged from global environmental norms and owned by dominant utilities (quiescent configurations), (c) located in nations lacking a

> system of political checks and balances and owned by dominant utilities and are old (expropriative configurations), or (d) located in the world-systems' core zone and owned by dominant utilities and are old (inertial configurations)."

In short, the pathways to pollution framework demonstrates that climate change is the result of various global, political, and organizational structural configurations. This dissertation expands the pathways to pollution framework by examining how the global and political environments in which the industrial organization is embedded, and the organizational characteristics of the facilities and the companies that directly operate them relate to venting and flaring in Texas. I conclude by describing the configurations leading to extreme venting and flaring in Texas and developing various policy recommendations to minimize routine venting and flaring.

1.5 Overview of Data and Research Methods

This research involves both primary and secondary source analysis. Primary data sources were collected from a variety of resources including industry reports, newspaper articles, law reviews, court records and Texas Railroad Commission archival documents obtained through Public Information Act requests for documents related to venting and flaring laws and policies. Secondary sources were analyzed upon being merged together using a geographic information system and unique well, lease, and operator identifiers. Wells are the surface locations for the hole in the ground where oil and gas are extracted. Leases are one or more wells on a plot of land upon which an operator can legally extract oil and gas according to Texas Railroad Commission and mineral rights contracts and laws. Operators are the company with direct legal ownership and responsibility for lease operators according to Texas Railroad Commission records. Secondary sources involved various Texas Railroad Commission datasets, the American Community Survey, the National Center for Charitable Statistics database, the LexisNexis Corporate Affiliations database, and the United States Energy Information Administration Intrastate and Interstate Natural Gas Pipeline Shapefile. A detailed discussion of the datasets used and how they were merged together is in *Appendix B* and *Appendix C*.

1.6 Organization of this Thesis

This dissertation is organized as follows. In the next section, I explore the politics of venting and flaring by the oil and gas extraction industry in Texas from the 1880s to 2010s. Using historical archival documents, I show that while in the late 1940s, anti-flaring policies forced companies to invest in the technologies and infrastructures necessary to collect natural gas that is otherwise vented or flared, amendments to statewide rules in the 1990s pursued by industry leaders created new opportunities for companies to legally vent or flare natural gas. The third section examines the communities most exposed to Texas oil and gas extraction industry venting and flaring practices. I use cross-sectional geographic datasets to map where most venting and flaring occurs and the types of communities most exposed. I find that neighborhood economic, political and racial inequalities relate to environmental inequalities produced by the oil and gas extraction industry. The fourth section explores the types of facilities and operators most responsible for venting and flaring. Using hierarchal cross-sectional data, I show that specific coercive, quiescent, expropriative, and inertial structures factors relate to oil and gas extraction industry venting and flaring practices. I conclude by developing five policy recommendations to minimize extreme routine venting and flaring practices. Since this thesis is organized like a book, detailed theoretical and methodological discussions and details are kept in the Appendix rather than the main text.

2. THE PROBLEM WITH REGULATION

> “We must proactively address flaring with fair, predictable, commonsense regulations based on science and fact. If we don’t, we can expect the anti-fossil fuel folks, including the EPA, to once again attempt to curtail oil and gas production in our state by using politically motivated rulemaking to implement their political agenda” (Texas Railroad Commissioner David Porter, 2012).

Texas state regulators are currently strongly opposed to curtailing oil and gas production to force companies to eliminate routine venting and flaring practices. Right now, with the support of the Texas Railroad Commission (RRC), the state agency responsible for regulating the Texas oil and gas industry, routine flaring is permitted with little administrative cost. However, this has not always been the case. In the 1940s, the RRC implemented no-flare bans and curtailed or completely shut down production at wells that failed to cease flaring and venting activities. Essentially, the RRC went from banning routine flaring and enforcing bans by curtailing production in the early twentieth century, to permitting routine flaring throughout the late twentieth and early twenty-first century. So, what changed? Why and how did the RRC ban routine flaring in the past? Under what conditions does the RRC now allow routine flaring? How and why is the RRC tackling the problem differently? To answer these questions, we must explore the political economy of the environment more deeply.

2.1 The Tragedy of the Commons in the Oil and Gas Industry

While Marxists have long argued environmental problems are linked to the unbridled self-interest ideology of capitalism, this idea did not become popular in the United States until 1968 when Harden published his famous article, “Tragedy of the Commons”. Using a metaphor of shepherds sharing a common pasture while pursuing their unfettered self-interest, the article demonstrates how free-market systems are destined for ecological collapse.

> As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility to me of adding one more animal to my herd?" This utility has one negative and one positive component. (1) The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1. (2) The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any decision-making herdsman is only a fraction of -1. Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another.... But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit--in a world that is limited. Ruin is the destination toward which all men rush, each

> pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all (Hardin, 1968: 1244).

The oil and gas industry faces its own tragedy of the commons. Numerous different producers with competing interests are each drawing from a shared field with a finite number of petrochemicals. Furthermore, as the field goes dry, it becomes costlier for producers to extract oil and gas. As such, a rational producer will attempt to extract more oil and gas faster than their competition. However, if everyone pursues their rational self-interest, the market would become flooded, the extracted resource would lose value, and the field would quickly run dry.

Due to the tragedy of the commons facing the industry, both industrial and citizen groups supported early efforts by the state to conserve oil and gas. These group efforts received common support, as the national conservationist movement neared its height. In response to growing concerns by the industry and conservationists alike, in 1917 the Texas state legislature proclaimed "…The *preservation and conservation of all natural resources* of the State are each and all herby *declared public rights* and duties and the Legislature shall pass all such laws as may be appropriate thereto." To create instruments to support their proclamation, the Texas Legislature passed Senate Bill 68, which provided the RRC with the resources and authority to set and enforce regulation limiting wasteful practices in the Texas oil and gas industry. The bill gave the RRC the power to: (1) set punishments against those that violate conservation laws through fines and jail sentences, (2) control pricing rates for the transportation of crude petroleum and natural gas, and (3) levy taxes to support the agency's efforts.

2.2 A Historical Approach to Class Power and Environmental Politics

While I have referred to the oil and gas industry as a group, it is not cohesive. The oil and gas industry is made up of numerous factions with competing interests. For example, since it is economically infeasible for producers to buy up the mineral rights to all lands where oil and gas is extracted, producers rely upon contracts with royalty owners to lease mineral rights. Royalty owners are the individuals that own the mineral rights of land and lease those rights to oil and gas companies for a portion of the profits. While this transaction requires agreement and cooperation, it is also riddled with conflict. It is within both groups' interest to keep a larger share of the profit and it is a zero-sum game. If the producer keeps a larger share of the profit, the royalty owner receives less. The industry is riddled with these types of conflicts between industry subgroups.

Political theorists have long debated how industry competition relates to the regulatory state (Akard 1992; Block 1980; Evans, Reuschemeyer and, Skocpol 1985; Lenin 1982; Marx 1867; Polanyi 1944; Poulantzas 1973; Prechel 1991). Much of the debate centers around who has political power in the modern social system: the capitalist class or professional bureaucrats.

Class theorists such as Marx (1867), Lenin (1982), and Poulantzas (1973) claim the state functions to support the ruling economic class. The state provides legitimate coercive power for capitalists to better achieve their interests (Lenin 1982). Rules and regulations, such as those that established and protected private property, are made to create and reproduce modern class relations (Polanyi 1944). Even though the capitalist class is split, and the state must maintain relative autonomy to resolve within-class conflict, the capitalist class can politically dominate by forming a power bloc consisting of a portion of leading industrial groups (Poulantzas 1973).

On the other hand, state autonomy theorists claim that professional bureaucrats, known as state managers, have the power to transcend class structures and control the regulatory state (Block 1980; Evans, Reuschemeyer and, Skocpol 1985). The interests of state managers are not the same as capitalists. State managers seek to use their knowledge and position to improve their status, sometimes using their political power to act in their own interests, regardless of powerful industrial actors. As such, the regulatory state cannot be reduced to the interests of the capitalist class. Because state managers are more unified and hold bureaucratic power, they can independently influence the structure and routines of the regulatory state, despite opposition from the capitalist class.

Historical contingency theory provides nuance to the debate by conceptualizing capitalist class power and state autonomy as two extremes on a continuum (Prechel 1991). While under some conditions state autonomy theory better explains political outcomes and class theory provides less, under other conditions the opposite occurs. From the historical contingency theory perspective, the political power of the capitalist class over state managers is related to how unified the industry is (i.e., when the industry is unified it can have power over the state), and business unity varies over time (Akard 1992). Some of the historical conditions affecting the distribution of power include economic downturns, as it provides urgency for organizations to create structures that will resolve immediate economic needs (Prechel 1991). Both the state and corporations are organizations that require economic resources and legitimacy to survive. When historical conditions increase capital dependence and uncertainty (like during economic downturns), corporations unify around prevailing public policy to change it in such a way that it better suits immediate economic interests. State regulation develops over time and reflects historical conflicts. During times of economic expansion and stability, state managers exercise control over the industry and during economic crises, the industry unifies to create state structures that better serve immediate capitalist interests.

Likewise, the development of Texas oil and gas conservation regulation is the result of historical conflicts where the dominating political group varies over time. In the early 20th century, the RRC maintained regulatory dominance over a highly fractured industry. However, as the global economy grew, the power of the RRC over the industry decreased. During an economic crisis in the late 1980s, the industry exercised its power to push the agency to deemphasize conservation and instead create flaring policy to better serve immediate corporate economic interests. I describe how changes in venting and flaring regulations relate to the historical political economy in the analysis section below.

2.3 Historical Analysis

2.3.1 Texas Oil and Gas Industry Regulatory Origins (1880s)

The oil boom in the early twentieth century transformed Texas, providing significant economic growth for the state. Exploration of gas began in 1892 when exploratory drilling was conducted on Spindletop Hill. Around this same time, U.S. motor companies began to produce automobiles. As the automobile industry began to expand, demand for and the value of crude oil increased. The oil industry in Texas exploded in 1901 in Spindletop with the eruption of Lucas Gusher. Shortly after, numerous new fields were opened, exploration and production expanded, and refineries were built. By the 1930s, Texas produced twice as much oil as any other state (Brown 2010).

However, the emerging industry was constrained by anti-trust laws and regulatory agencies established from populist triumphs throughout the late 1800s. One key agency established from the populist movement was the RRC. Upon campaigning to better regulate railroad monopolies, Governor Jim Hogg worked with the state legislature to establish the RRC in 1881. By creating the RRC as an appointive agency, Governor Hogg aimed to avoid situations where the industry could buy elections. He appointed the first three commissioners: Senator John Reagan, Judge W.P. McLean, and L.L. Foster. However, a few years after the agency was established, the Texas Constitution was amended to change the agency to be run by three elected commissioners. Each commissioner holds a six-year term and there are elections every two years. If a commissioner steps down, the governor has the power to appoint a new commissioner to serve until the next election. The creating of the RRC as an elected agency rather than appointed one had long-term consequences on industry-state relations, especially with big money in modern politics. Governor Hogg's fears have come to life, yet, because the agency now functions primarily to regulate oil and gas rather than railroads, it is the oil and gas industry, not the railroads, that pour money into elections so that industry candidates dominate. For example, the 1976 TRC election of the Jon Newton over populist Jerry Sadler was strongly influenced by industry leaders. Over $285,000 came from contributions of $500 and over and 73% of those contributions were traced to just a few oil and gas producers (Prindle 1981). In short, the creation of the RRC as an elected agency regulating railroads ended up having long-term consequences on the regulation of the oil and gas industry.

2.3.2 Political Conflict During the Gusher Age (1900s-1930s)

While regulation is often viewed as bad for capitalists, upon the establishment of the oil and gas industry in Texas, capitalists supported regulation to enforce contracts and coordinate a fragmented market to prevent over-production. During the first Texas oil boom, the state served the function of mediating conflict among capitalists, rather than between capitalists and the working communities in which capitalist facilities are located. In an attempt to juggle competing capitalist interests, early venting and flaring policies continuously changed.

In the early days of the industry, the state and industry battled over what is considered waste, especially with regards to venting and flaring. At oil and gas wells, companies extract a mix of oil, non-associated gas (i.e., raw natural gas), associated gas well gas (i.e., raw natural gas mixed with oil and other hydrocarbons at a gas well) and/or casinghead gas (i.e., raw natural gas mixed with oil and other hydrocarbons at an oil well). While oil is considered "black gold" because of its high economic value, natural gas extracted along with the oil held little value in the early marketplace. In attempt to extract the largest amount of oil, fastest, and with the least amount of initial expense, rather than purchasing the equipment to collect, store, and transport the extracted natural gas, many operators chose to waste the finite natural resource through venting or flaring.

Early venting and flaring policy developed as the state served the function of mitigating conflict between competing class segments within the oil and gas industry. For instance, the first regulations developed as an attempt to ease conflict between producers and royalty owners (i.e., those who own the rights to drill on Texas land). Conflict between these two groups was divided over what was considered necessary waste. Some companies must compensate the owners of the mineral rights (i.e., royalty owners) through royalty payments. While operators profit from quickly (and not always carefully) drilling, extracting, and collecting the more valuable oil and moving on once the well goes dry, royalty owners can only profit from selling the finite number of natural resources on their land. In short, natural gas royalty owners saw flaring non-associated gas (i.e., the primary commodity of a natural gas well) as unnecessary waste that they could not profit from. On the other hand, production companies saw flaring non-associated gas as a sometimes-acceptable waste in pursuit of immediate profits. Consequently, royalty owners urged state leaders to ban the venting and flaring of non-associated gas at gas wells so that the natural resources they owned could be better protected from production company waste through venting or flaring. State managers supported the royalty owners because vented or flared gas also resulted in lost state revenue. Gas that was vented or flared was not subject to state tax; the valuable natural resource is simply released into the air. In short, once released into the atmosphere through venting or flaring, the natural resource lost all economic value. For this reason, in 1899 Robert Prince of Corsicana led the state legislature to ban the venting and flaring of non-associated gas 10 days after the drilling of a gas well is completed (Texas Congress 1899).

Competing for profits in the expanding industry, throughout 1918 and 1919, royalty owners, federal regulators, gas refineries (who would profit from processing associated gas that was currently being flared), and conservationist producers pressured state managers to expand flaring policies to better enforce early natural gas and oil conservation regulations by questioning the adequacy of state-level environmental governance. For example, the United States Fuel Administration named inspectors to investigate the waste of natural gas in Texas (*Dallas Morning News* 1918). In another public act criticizing the adequacy of state regulation, the

Wichita County Producers and Refiners' Association announced producers would be working with local police departments to enforce conservation laws since state-level enforcement was inadequate (*Dallas Morning News* 1919).

With legitimacy at risk, the state reacted by enhancing and exercising their authority to regulate oil and gas. In 1919, Senator Carlock of Fort Worth introduced Senate Bill 350, which gave the RRC the authority to regulate Texas oil and gas production practices (Texas Congress 1919). This law mandated each company provide the RRC with thorough records of oil and gas operation, production, and disposal activities. Furthermore, the bill forced organizations to obtain a certificate of compliance to RRC regulation to lawfully operate in the state. This law allowed the RRC to regulate oil and gas production and limit production to minimize waste. Since, until the Organization of the Petroleum Exporting Countries (OPEC) was established in the 1960s, Texas controlled a major portion of the world's discovered oil and gas reserves, this law empowered the RRC to significantly influence world gas prices (Prindle 1981). In 1931, RRC's first proration order (i.e. a legal order limiting well production) went into effect. Although oil and gas production company leaders defied state regulatory efforts, Governor Sterling (1931) declared martial law, forcing corporate compliance.

Despite state efforts to better conserve gas, throughout the 1920s, the oil industry successfully resisted the efforts of state managers, royalty owners, pipeline companies, and refinery companies to ensure state policy provided legal opportunities to flare gas at oil wells. For example, in 1925 after a royalty owner filed suit against an oil production company, the resulting legal rulings required producers pay royalties for sold casinghead gas, yet producers are not liable for economic losses to royalty owners from wasted gas (Livingston Oil Corp v. Waggoner). Because legal developments explicitly prohibited flaring at gas wells but not oil wells, state managers were met with the difficult task of differentiating between oil and gas wells and then only enforcing flaring bans at designated gas wells.

Despite resistance from state managers, due to oil industry lobbyist efforts, the state legislature continued to develop and support state laws which excluded oil wells from flaring regulations. For example, in 1931, prominent Texas state officials, including Governor Neff (1931) and Railroad Commissioner Parker (1931) testified to the state legislature in support of more stringent conservation laws. However, oil producers opposed regulatory efforts; they argued that regulating flaring at oil wells would stop the economic boom occurring within the state (*Dallas Morning News* 1931). During this period of time, Texas was highly reliant upon the oil industry's tax revenue. In 1931, the tax revenue directly from the oil industry brought in over $82 million, almost 30% of all state revenue (Texas Almanac 1931). Therefore, the newly emerging Texas oil industry held significant power over state legislatures, who greatly benefitted from the economic growth of the industry. Despite the resistance of state managers, economic dependence and oil industry arguments motivated the state legislature to support the oil industry over conservationists. Texas legislature passed House Bill 25, which emphasized the RRC's authority to regulate flaring at gas wells, but not oil wells (Texas Congress 1931).

In sum, during the first oil boom, the oil and gas industry was split into various factions. Oil and gas conservation policy regularly changed as competing industrial groups conflicted over regulation. The RRC played the role of managing conflict within a resistant industry. This conflict resulted in laws that provided the RRC with the power to curtail production to minimize waste yet excluded oil wells from flaring regulations.

2.3.3 The Advancement of Conservationist State Leadership (1930s-1950s)

As the Texas oil boom peaked, capitalists continued to be split over regulation. Since the capitalist class was not unified, the state had greater regulatory power over capitalist resistance to environmental regulation. With prevailing state policy and without unified political resistance, during this period, state managers had the power to force companies to invest in the technologies and infrastructures necessary to minimize flaring, which it exercised through scientific and legal means.

Despite oil industry resistance, state managers could expand their authority to regulate flaring at wells by supporting the development of scientific knowledge in the newly emerging industry and transforming legal context through litigation. For example, the RRC hired chemists from the University of Texas to test water-white oil and determine if the substance should continue to be classified as oil (Prindle 1981). Upon raising the temperature and pressure, the chemists found the white-water oil turned into natural gas. This new scientific discovery resulted in hundreds of oil wells being reclassified as gas wells. Since at this point of time, flaring was banned at gas wells, but not oil wells, by reclassifying facilities as gas wells, facilities were no longer legally allowed to flare gas. As a result, the RRC issued “no flare orders” which forced operating companies to shut down well production until the company built adequate infrastructure to capture the gas. In 1932 (Henderson v. Railroad Commission), upon being sued by an independent producer for shutting down the wells, the RRC argued regardless of the well’s classification, flaring is an economic waste and within the RRC’s regulatory jurisdiction. The court agreed, providing legal precedent for the RRC to regulate flaring at both oil and gas wells.

Although the courts held legal precedent for the RRC to enforce polices to minimize waste at both oil and gas wells, conflict within the industry resulted in inconsistent state legislation. For instance, although policy instituted in 1931 banned flaring gas at gas wells, after pressure from gas stripping companies in East Texas, the state legislature passed Senate Bill 92 (1933). The bill permitted operators to flare gas at gas wells when there is "no reasonable market available" (Texas Congress 1933:222). However, the industry did not cohesively support the bill. Pipeline companies, who economically benefitted from the state forcing companies to transport gas, resisted through an anti-waste lobbying campaign (Prindle 1981). In response, the state legislature held hearings from April 9-12, 1934. Land owners, pipeline companies, refineries, royalty owners, producers, and other industry representatives attended the hearings regarding wasteful flaring practices (Texas Congress 1934).

In 1935, the RRC teamed up with pipeline companies, land owners, refineries, and royalty owners to implement a consistent policy that explicitly banned flaring, regardless if there is "no reasonable market available." With the support of land owners, royalty owners, refineries, and gas pipeline companies, in 1935 the Texas Congress overturned Senate Bill 92 by passing House Bills 266 and 782. The policies enhanced the RRC's authority to prevent waste by shutting down gas wells that flare gas 10 days after drilling is completed, regardless of economic viability. But still, the state legislature avoided conflict with the oil industry by excluding discussion regarding flaring at oil wells. When the RRC exercised its power by shutting down flaring gas wells, producers responded by filing suit. However, the courts maintained the legality of the shutdown orders (Clymore Production Co. et al. v. Thompson et al. 1936).

After this point, state law regarding oil and gas flaring regulation remained unchanged until the 1970s. In short, by 1935, state policy was institutionalized through three mechanisms:

(1) the state legislature explicitly banned flaring gas as gas wells without mention of flaring at oil wells, (2) the RRC held the authority to regulate production and waste in the oil and gas industry, and (3) state courts provided legal precedent for the RRC to shut down wells that fail to cease wasteful practices (such as routine flaring), regardless of the well's oil or gas classification.

In the mid- to lat-1940s, anti-waste activists used prevailing state policy to institute a strong anti-flaring campaign within the RRC. The campaign gained steam in 1944 during a hearing, when anti-flaring activist and former RRC employee, William Murray, vigorously argued RRC official figures on waste were grossly underestimated; tax payers and royalty owners only knew of a fraction of the total amount of natural gas wasted from routine flaring practices. Forced to respond to his scientifically-informed, public critique, the RRC appointed Murray to chair a committee to investigate waste from industry production practices. Once completed, the Murray Committee report revealed the large amount of gas wasted through flaring (Prindle 1981).

Although some industry representatives resented the Murray Committee report, the industry was not unified in opposition to strong state-level anti-flaring efforts. For example, Dan Moran, the president of Conoco, provided public support for the Murray Committee and argued that for the sake of the long-term interests of the industry, flaring had to stop (Prindle 1981). Public support by some industry leaders legitimized RRC anti-flaring efforts.

The Murray Committee report increased national concern with the waste of natural gas, prompting federal government involvement. In 1946, the Federal Power Commission held hearings regarding gas waste in Texas. Out of fear of federal intervention, more oil industry leaders began to support strong state-level anti-flaring regulation. Supported by the oil and gas industry, governors around the United States formed a coalition to support state-level regulatory control: The Interstate Oil Compact Commission. The Interstate Oil Compact Commission directly lobbied for states to support strong, state-level anti-flaring efforts. In response to increased pressure from both within the state and across the nation, the Texas Governor appointed William Murray to serve in a vacant RRC Commissioner seat, an action supported by the Interstate Oil Compact Commission (Morehead 1947).

Shortly after William Murray was appointed to the vacant RRC Commissioner post, the RRC began to implement strong conservationist policies, curtailing production until producers ceased wasteful flaring practices. The RRC issued an order to shut down 615 oil wells in South Texas until corporations built the infrastructure to prevent flaring casinghead gas (Wells 2014; Prindle 1981). Corporations filed suit. The Texas Supreme Court held the RRC could shut down flaring oil and gas wells since state legislation authorized the RRC to implement policy to minimize waste in the oil and gas industry (Railroad Commission v. Shell Oil 1947).

In brief, Texas state policy regulating flaring at oil and gas wells emerged before the turn of twentieth century. Responding to threats of federal intervention during a period of economic growth, the governor appointed a conservationist and anti-flaring activist engineer as a RRC Commissioner, William Murray. With the support of key state and industry leaders, Murray emerged as a strong conservationist leader who used the power of the state to shut down wells until they built the infrastructure necessary to eliminate routine flaring. Because of Murray's efforts, the industry was legally forced to minimize flaring practices by investing in the equipment necessary to capture natural gas and either reinject it into an underground reservoir or build the infrastructure necessary to transport natural gas to consumers.

2.3.4 State Responses to Globalization (1960s-1990s)

While prior to globalization, Texas controlled most of the known oil reserves, upon the rise of the global marketplace, the RRC is no longer the regulatory powerhouse it once was. As the result of busts, increased global competition, and industry cohesion, RRC policy became increasingly influenced by capitalists. Thus, during this period, policy shifted to increase the legal opportunities for oil and gas companies to flare natural gas.

In 1960, the Organization of the Petroleum Exporting Countries (OPEC) was established, overtaking the RRC's power in setting gas prices by regulating a major portion of the world's oil production (Prindle 1981). As the oil and gas industry globalized, the RRC no longer held regulatory control over most of the known oil and gas reserves. In this way, globalization decreased the power of Texas state managers. By the late twentieth century, oil companies exercised their power to change RRC policy to allow legitimate routine flaring at oil wells.

The power of OPEC to influence oil and gas prices created new industry pressures. The 1970s Middle East crisis resulted in an OPEC oil embargo and gas prices rose (Cross 1970). As the nation faced a natural gas shortage, producers were pressured to supply national demand. However, Texas oil and gas producers aimed to avoid federal regulation, specifically the 1938 Natural Gas Act, which gave the federal government authority to set prices and sales for all gas transported through interstate pipelines. As a result, although Texas faced an oversupply of gas, producers failed to sell the gas to customers across state lines during a period of national shortage.

The 1970s oil and gas crisis also created new risks for the RRC. The RRC came under intense scrutiny because, while the nation faced a shortage, Texas dealt with a surplus because producers refused to sell gas across state lines to avoid the 1938 Natural Gas Act. To manage oversupply, the RRC ordered a prorationing of gas, limiting Texas gas production. This regulatory action acquired national attention in 1978, when, on the popular national news program "Face the Nation," Senator Henry Jackson directly accused the RRC of price fixing and suggested federal control of Texas gas (Prindle 1981). The RRC and the industry were forced to do something in response.

In response to external political and economic pressures, the oil and gas industry politically unified to claim prevailing state regulation established organizational complexities which created legal and economic disincentives for the industry to meet national needs. Industry representatives argued that failures to supply natural gas were the result of inflexible and unclear regulations impeding the discovery of new gas wells and deterring sales of gas across state lines. The federal government conceded to industry arguments and amended the 1938 Natural Gas Act to end federal regulation of natural gas prices sold across state lines (Walden 2008).

Under pressure to better regulate the industry and facilitate growth, the RRC was also forced to respond. However, with the industry unified, corporate hegemony (i.e. corporate dominance over ways of thought) limited the viable options of state actors. Furthermore, as elections started to become more expensive, RRC leaders became increasingly dependent upon industry financial support for political elections. Accordingly, the RRC responded by regurgitating industry framing of the problem. Statewide Rule 32 was passed, "to provide needed flexibility in gas operations," (Texas Register 1978: 1020). Like previous regulation, Statewide Rule 32 banned flaring of gas at gas wells 10 days after drilling is completed. However, the rules provided opportunities for bureaucratic exemptions; gas well operators could file a request to legally flare gas due to cleaning and repair needs. The RRC held the responsibility of implementing a permit system and fining gas wells that flared without obtaining a permit. However, the RRC did not receive adequate funding to manage their increased administrative burdens.

Throughout the 1980s, oil and gas companies were again under threat from RRC anti-flaring regulatory actions. Without administrative code regulating flaring casinghead gas at oil wells, legal precedent provided state managers with the capacity to restrict the production of flaring oil wells. Due to increased flaring activity, RRC engineers recommended operators cease wasteful flaring practices (Singletary 1982). Examiners found, despite adequate pipeline infrastructure, operators were flaring gas in the Giddens Field area (Singletary 1982). In response, regulators issued no flare orders for Giddens Field, limiting the production of wells in the area (RRC 1982). In 1986, due to continued waste, the RRC limited the production of oil wells throughout the entire state (RRC 1986).

The RRC was pressured to initiate strong anti-flaring actions out of fear of loss or dual regulatory control by other state and federal agencies. For instance, the Environmental Protection Agency (EPA), began to pressure the Texas Air Control Board (TACB) to meet federal ozone standards. As part of its response, TACB scrutinized emissions from oil and gas flaring practices and contacted the RRC (Bradford 1986). The RRC feared external intervention into their affairs and took actions to protect its regulatory authority. RRC officials responded by arguing against dual regulation by both TACB and RRC; in a letter they state TACB did not need to regulate flaring because RRC policy is enough (Hall 1986:2). To maintain their authority and legitimacy as the sole regulator of Texas oil and gas well flares, the RRC was again pressured to respond. "In order to prevent avoidable physical waste" (RRC 1987: 1), rather than simply limit production, the RRC issued shut down orders for flaring gas. Thus, the oil industry faced increased threats of the start of a new wave of strong anti-flaring regulatory actions.

Economic and political threats motivated the oil and gas industry to unify and cohesively respond in opposition to strong RRC anti-flaring policy. After increased production in response to the oil shortage of the 1970s, an oil glut created economic turmoil for oil and gas production companies in the 1980s. Strong anti-flaring state policy threatened corporate profits, as companies with few liquid assets preferred to expediently extract oil and burn excess gas, rather than invest in the infrastructure and technology necessary to bring extracted natural gas to the market. Accordingly, companies mobilized to erode prevailing state policy which allowed the RRC to shut down flaring oil wells.

Economic and legal threats motivated corporations to unify politically to erode flaring regulations within the RRC. The RRC responded to industry opposition to strong anti-flaring regulatory actions by inviting interested parties to speak at public hearings. During the hearings, the industry cohesively argued flaring regulations were too burdensome. Industry officials focused on economic expediency and the currently low gas prices (Shook 1985:16):

> Dan H. Montgomery, president of Houston-based Comet Resources, is concerned that producers' inability to sell gas is going to affect oil production. Montgomery explained that TXRRC regulations prohibit producers from flaring the casinghead gas produced by many oil wells and reinjecting the gas into the oil reservoir may not be possible. "Casinghead gas can't be sold, it can't be transported and it can't be flared," he said. "Producers are going to have only

> two choices: shut in an oil well or give the gas away. They lose money either way because they still have to pay the land owners royalties on the production."

By employing economic rationality throughout the hearing, industry leaders claimed immediate economic interests must supersede RRC anti-waste efforts. Even after the hearings, industry officials continued to publicly argue that state anti-flaring regulations threatened state revenues (Shook 1988).

The oil and gas industry used prevailing public policy as a tool to increase legitimate opportunities to waste gas through flaring. Industry efforts in opposition to strong anti-flaring state policy centered on amending Statewide Rule 32. Following industry recommendations, the RRC announced plans to amend policy to include rules for flaring casinghead gas and extend the conditions under which flaring is considered necessary. The proposed amendment expanded the conditions to include the "unavailability of a pipeline or other marketing facility, or other legal uses" (Texas Register 1990a:1680). Upon the passage of the amendment, a permit is approved not just for cleaning and repair (like previous policy), but if the producer claims because pipelines have not been built, not flaring would result in economic delay.

In addition to allowing flaring for immediate economic reasons, the proposed amendments minimized administrative burdens for routine flaring at low-producing wells. The following section was added (Texas Register 1990a: 1680):

> The Director of the Oil and Gas Division, or the director's delegate, may administratively grant exceptions in the manner authorized by subsections (a)(2), (b) and (c) of this section. Exceptions granted pursuant to this subsection may not exceed a period of ninety (90) days; provided that, the ninety-day

> limitation does not apply for volumes of casinghead gas less than or equal to 5 mcf per well per day.

This policy change minimized the administrative cost for wells flaring 5 mcf or less of gas *each day*. To put this number in context, in 1990, the average U.S. residential consumer used 95 mcf *each year* (EIA 2010).

With industry push, RRC state managers again regurgitated oil industry economic framing of the problem while overlooking its anti-waste institutional foundation. For example, the RRC emphasized the need to minimize administrative burdens and acquiesced to Exxon's request for a higher exemption threshold. Corporate representatives wrote to the RRC (Hutchinson 1990:1):

> Exxon Corporation supports the Commission's proposed changes to Statewide Rule 32 with one exception. Exxon recommends that Section (d) be revised to allow the Director of the Oil and Gas Division or his delegate to administratively approve exceptions to subsections (a) (2), (b), and (c), without a ninety-day limitation for volumes of gas less than or equal to 25 Mcf/day. The volume limitation in the proposed rule will impose an undue administrative burden on both the Railroad Commission and industry.

As a result, the Commission appointed Mimi Winetroub to review the argument. Legitimizing Shell's argument, Winetroub (1990:1) recommended the changes be approved since it would limit the administrative burden of the permit process (for both state managers and corporations):

> Only 23 leases per month (average) flare/vent volumes greater than 25 MCFD. On the other hand, the existing proposed rule with a cut-off of 5 MCFD would place a maximum of 80 cases before the Commission each month…. Exxon Company U.S.A. filed a comment in agreement with the staff recommendation.

Following Exxon's recommendation, the RRC increased the limit from 5 mcf/day to 25 mcf/day (Texas Register 1990b). In short, through direct lobbying, Exxon and other oil industry efforts increased the opportunities for producers to legally flare gas.

Statewide Rule 32 amendments minimized the risk and cost of corporate non-compliance. Flaring regulations shifted from issuing shut down orders to issuing fees for violating Statewide Rule 32. Fines can be issued for up to $10,000 each day the well flares without a permit. However, fees are rarely issued (Hiller and Tedesco 2014). Instead, the RRC sends warnings to pressure violators to comply to state policy by filing for a flaring permit, which is rarely denied. Individual royalty owners and landowners surrounding a property can sue producers for negligent waste (Wells 2014), but state structure fails to enforce a strong, comprehensive, anti-flaring policy. Instead, current state structure provides corporations with the capacity to legitimately flare gas, and wells continue to flare gas when economically beneficial (McFarland 2014).

In conclusion, globalization decreased the power of state managers over the industry. By the 1970s, OPEC began to have greater control over oil and gas prices. Subsequently, economic downturns pressured state managers to work with the industry to change conservation policy to better meet the immediate economic interests of the industry. State managers employed economic framing to change policy to allow flaring for economic expediency.

2.3.5 Modern Flaring Politics (2000s-2010s)

The change in policy in the 1990s had major consequences during the shale oil boom. With the legal opportunity to do so, many companies have chosen to immediately drill for oil and flare natural gas rather than wait to build the pipeline infrastructures necessary to collect gas in remote fields where oil and gas had been inaccessible until the development of shale drilling technologies, such as fracking. As a result, during the shale oil boom, many communities have been plagued by flaring at oil and gas well sites.

Increased flaring activities during the shale oil boom resulted in increased public concern. Although the industry and state support an economic framing of the issue, environmental activists and health researchers continue to increase public awareness of the environmental, health and economic costs of flaring and venting by the oil and gas industry. Since the 1990s, companies continue to develop technology to reduce flaring and venting emissions (Montgomery 1996). However, many companies fail to invest in new technologies and venting and flaring continues to be a major problem facing local communities. As venting and flaring became more prevalent during the shale oil boom, communities and corporate shareholders mobilized in opposition. Scientists and environmentalist groups released reports about the impact of flaring on local community health (Morris 1997). Increased citizen concern prompted private investors to call for corporate managers to address the issue (Hayes 2007). Furthermore, oil and gas lawyers have called for individuals to sue companies for wasting natural resources and exposing residents to pollution by unnecessarily flaring natural gas (Wells 2014).

While anti-flaring activists have targeted corporations to minimize venting and flaring, corporate managers blame venting and flaring activities on federal regulations, specifically the

EPA (Tedesco and Hiller 2014). Due to increased concern with global climate change, in 2011, the EPA set new greenhouse gas limits. Although, as a result of industry pressure, EPA policy exempted oil and gas wells and pipelines, the regulations still apply to other gas infrastructures, such as processing plants. While some companies overcome constraints by investing in new portable equipment, industry representatives publicly claim flaring is inevitable because EPA regulations prohibit companies from getting quick approval to build the infrastructure necessary to capture gas (Landers 2012).

Aiming to maintain their authority over an industry they are highly dependent upon, state managers within the RRC have aligned with corporate managers in opposition to federal regulation. In a testimony to Congress, RRC Chairman Barry Smitherman argued in support of industry and in opposition to federal environmental regulations (2013): "The key to keeping our nation's natural gas momentum going is to limit interference from EPA." Because of continued cohesive industry opposition to federal environmental regulations and in attempt to maintain state authority, the Texas Attorney General sued the EPA (Hiller and Tedesco 2014).

Whereas corporate-state relations were more contentious in the early twentieth century, the early twenty-first century corporate-state relations are more cooperative. State oil and gas regulations have shifted to support cooperative voluntary efforts established in coordination with the industry (*Dallas Morning News* 2013). These cooperative efforts between the state and corporations soothe environmentalist concerns without making significant structural changes. For example, in 2011, to address the problem of flaring, the RRC initiated the Eagle Ford Shale Task Force in coordination with industry officials and headed by RRC Commissioner David Porter. The Task Force was praised by industry leaders (McEwen 2012):

> Robison [chairman of the Permian Basin Petroleum Association (PBPA)] praised Porter for taking the initiative on the issue, saying its important flaring is addressed within the state by state regulators before federal regulators step in and address the issue. Porter, he added, has done a good job of keeping the PBPA and other associations in the loop as he studies what can be done and what needs to be done to minimize flaring and its impact on the population.

However, the Task Force did not result in structural changes to limit flaring. Instead, the Task Force argued the flaring problem would be reduced if regulations were clearer and permits were granted at a faster rate (Vaughan 2013). Because of the Task Force's findings, the state legislature provided the RRC with a $24.7 million supplemental appropriation to digitize oil and gas reporting requirements and permit applications (Vaughan 2013). Although these administrative efforts speed the process of obtaining a flaring permit, changes do not limit routine flaring. Through membership on state-led environmental interest committees, corporate interests are achieved while placating environmentalist stakeholders.

In sum, regulations established in the 1990s created legitimate opportunities to flare gas. Many companies seized this opportunity during the shale oil boom. As a result, gas is frequently flared at well sites, and the once-banned activity of flaring is now more of an industry norm. However, rather than forcing companies to not routinely flare gas from an adversarial standpoint, the RRC now works with the industry to enhance and maintain legitimate opportunities for companies to flare gas.

2.4 Summary of the Problem with Regulation

Current Texas flaring regulations are problematic because they provide legitimate opportunities for companies to routinely flare gas. In other words, there are few political checks and balances to corporate power to pollute. All companies can obtain a permit to legally flare gas. Furthermore, administrative burdens to routinely flare 25 mcf/day are minimal, as permits do not have to be renewed. In short, the RRC provides legitimacy for industry routine flaring practices while providing few burdens. Current policies significantly differ from the RRC's strong anti-flaring campaigns in the 1940s.

Often regulatory organizations shift from their intended purpose due to external institutional pressures (Selznick 1948). In this case, oil industry norms for minimal administrative costs and prioritization of immediate economic interests became increasingly accepted at the RRC, shifting it from its populist and conservationist roots. As globalization decreased the regulatory power of the state, the RRC became increasingly reliant on industry support. As such, during a period of economic decline when the industry unified in opposition to prevailing policy, state managers adopted industry norms and language as they developed changes to conservationist policies. These changes led to increased opportunities for companies to legally flare gas.

In conclusion, the power of the environmental state varies over time and does not reliably prioritize conservation over the immediate interests of the capitalist class. This is especially true in the modern globalized world. Because the state depends on tax income to survive and competes with others in the global economy, the neo-liberal global political economy has created a "race to the bottom" among state environmental regulators. While, in the 1940s when the industry was still booming, the RRC held the power to regulate a large portion of the world's producing oil and gas fields, that is no longer the case. Now the RRC is subject to regulatory competition. To entice development in the globally competitive industry during economic busts, the RRC shifted its administrative power to prioritize the immediate economic interest of the industry by increasing the legal opportunities for operators to vent or flare gas, despite the long-term environmental, health, and economic consequences.

3. ENVIRONMENTAL INEQUALITY FROM FLARING AND VENTING

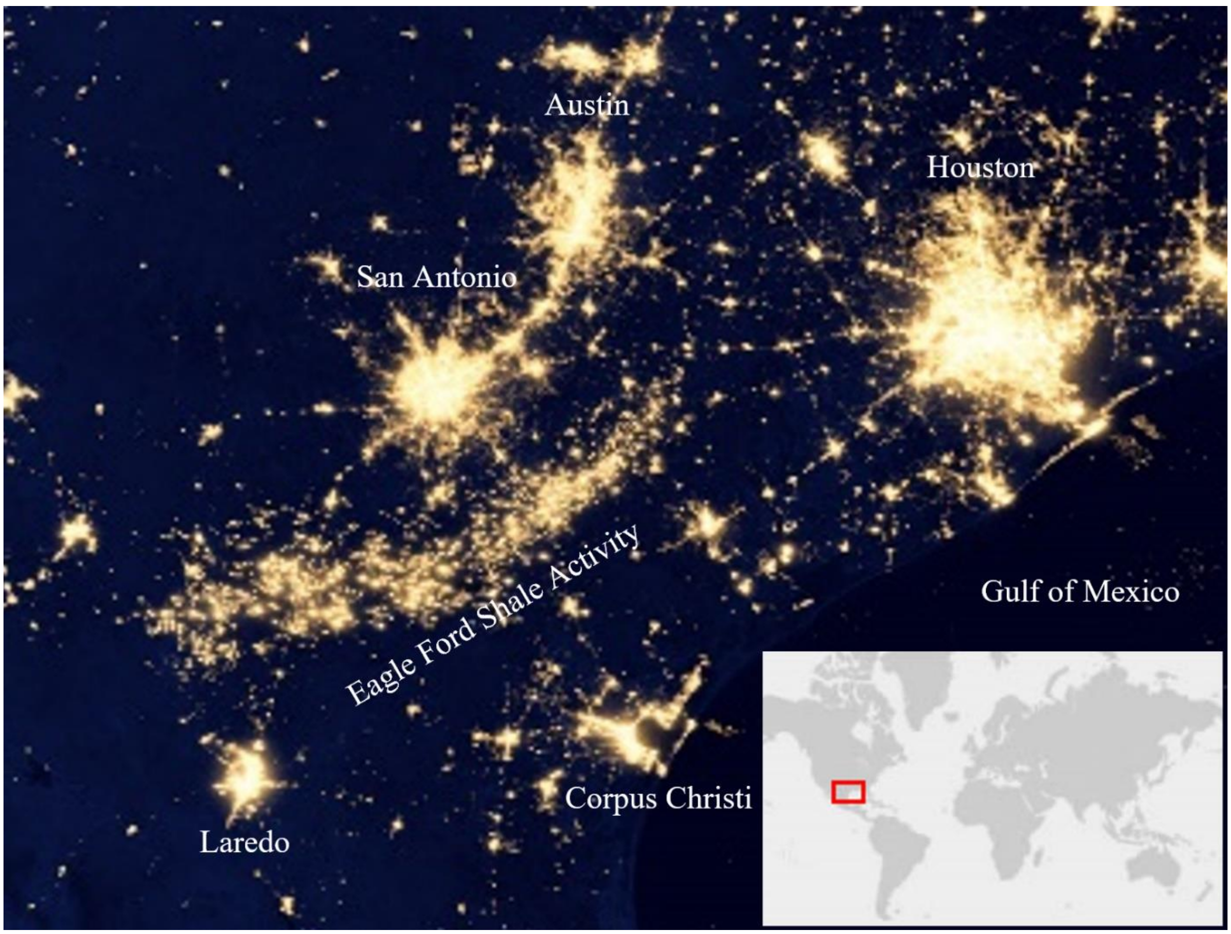
> "We went from nice, easy country living to living in a Petri dish. This crap is killing me and my family" (Cerny 2014).

While focus on the harmful environmental effects of shale fracking technologies tends to be on issues with water quality from the injection process, poor air quality from venting and flaring is also a major concern; fracking well sites vent 30% more methane gas than traditional natural gas production facilities (Howarth, Santoro, Ingraffea 2011). Residents in areas most affected by the shale oil boom report experiencing respiratory problems from the volatile organic compounds like sulfur dioxide, benzene, carbon monoxide, and carbon disulfide from flaring and venting at production sites (Morris, Song, and Hasemyer 2014). However, because the Texas Railroad Commission permits facilities to legally flare and because most residents do not own the mineral rights on or surrounding their land, individuals and communities have few legal resources to resist exposure. This section examines how the oil and as industry's venting and flaring affects air quality in affected communities.

3.1 Community Concern with Flaring and Venting

While venting is a near invisible release of natural gas, flaring has an immediate visual impact. For example, from space, rural areas surrounding the Eagle Ford shale look like metropolitan cities due to the prevalence of gas flares (See *Figure 3*). The visual impact of flaring at Texas oil ang gas wells is not new. During the early 1900s, gas flares were a light pollution problem (Prindle 1981). Wells (2014:326) describes life during the first oil boom: "According to many accounts, motorists could drive for hours at night in parts of Texas and never turn on their automobile lights because the casinghead gas flares illuminated the countryside. Newspapers could be read at night by the light of these flares. From the air, West Texas was said to look as if campfires of all the armies in the history of the world were burning below." We see this light pollution again today.

Figure 3. Eagle Ford Shale Activity



Source: NASA, 2012 [Adapted]

However, modern concerns move beyond just what humans see, and towards understanding the effect on the ecosystem as a whole. Venting and flaring is now understood to have both large- and small-scale ecological and health effects.

Venting and flaring results in large scale ecological effects by contributing to global climate change. Venting primarily releases methane gas into the atmosphere. Increased methane emissions by the oil and gas industry is of global concern because methane is more efficient at trapping heat in the atmosphere. In fact, over 100 years, methane is over 25 times more potent of a greenhouse gas than the same amount of carbon dioxide. Flaring also releases greenhouse gasses such as methane and carbon dioxide, which significantly contribute to climate change, as well as other atmospheric contaminants, including nitrogen dioxide, sulfur dioxide, carbon monoxide, carbon dioxide, hydrocarbons, and hydrogen sulfide.

The ecological effects of venting and flaring are also small scale. Contaminants released during the venting process combined with the heat associated with the burning of natural gas during the process of flaring are detrimental to the surrounding ecological environment (Ajugwo 2013). Heat from flaring at oil and gas extraction facilities can create ecological dead zones 30 meters from the facility, negative impacts on vegetation 100 meters from the facilities, and the number of species surrounding the facilities are significantly smaller and less diverse (Isichei and Sanford 1976).

Venting and flaring also affects health outcomes, as humans and animals become exposed to hazardous air pollutants released throughout the venting and flaring process. For example, research shows these practices can cause neurological, reproductive, and developmental effects in vulnerable communities (Ajugwo 2013). Furthermore, children exposed to flaring pollutants have reported hematological, breathing, and skin problems (Effiong and Etowa 2012).

Overall, exposure to air pollutants from venting and flaring has a negative impact on human health and the ecosystem as a whole. However, the immediate health hazards from venting and flaring are not equally distributed throughout the population; some groups are more exposed than others. So which groups are most likely to experience poor air quality due to venting and flaring activities? This is the focus of the rest of this section.

3.2 Environmental Justice Theoretical Debates

Environmental justice is the idea that everyone, regardless of race, income or culture, has a right to live in a healthy environment. Environmental justice is considered a solution to two main problems in society: environmental racism and environmental inequality (Pellow 2000). Environmental racism is a term that suggests communities of color are disproportionately affected by environmental risks, whereas environmental inequality is a term that focuses on how a wide array of intersecting social hierarchies (e.g., class, race, age, language and disability) affects an individual's access to a healthy environment (Pellow 2000). From the environmental justice perspective, environmental sustainability is better achieved through environmental justice. Without the ability to target marginalized populations while personally avoiding environmental risks, environmental decision makers are more motivated to invest in green technologies. In this way, environmental equity will not only improve the conditions of the most vulnerable groups, it will also improve the environmental quality for the general population (EPA 1992).

Environmental justice research focuses on how socially vulnerable communities are disproportionately affected by industrial pollution (Bullard 1990; Pellow, Weinberg and Schnaiberg 2001). There are numerous community characteristics associated with social vulnerability and environmental risk (Cutter, Boruf and Shirley 2003). These characteristics include economic/poverty status (Wilson, Fraser-Rahim, Williams, Zhang, Rice, Svendsen and Abara 2012), education (Wilson et. al. 2012) and race (Bullard 1990; Pais, Crowder and Downey 2014).

While environmental justice research commonly focuses on how environmental pollution disproportionately affects socially vulnerable populations, there is debate over why socially vulnerable groups are exposed. Three key explanations exist: the economic model, the political action model, and the pure discrimination model (Hamilton 1995; Saha and Mohai 2005).

3.2.1 An Economic Explanation of Environmental Inequality

Environmental inequality may occur due to rational economic processes. This perspective portrays both industrial producers and residential consumers as rational economic actors. It suggests that industrial producers weigh the number of people potentially exposed to pollution, the potential liability, and the property costs when deciding where to locate high polluting facilities. Weighing these costs, in general, they choose to locate high polluting facilities in socially vulnerable communities because doing so is generally cost effective (Pastor, Sadd, and Hip 2001). Likewise, residential consumers weigh costs and benefits when making residential decisions. Due to different economic circumstances, high-income individuals have more opportunity to prioritize access to a healthy environment (Princen 1997). Furthermore, because residents prefer access to a healthy environment, areas with fewer environmental risks are associated with higher rent costs and land values, and geographic areas with more toxic hazards tend to have lower rent costs and land values (de Palma, Motamedi, Picard, Waddell 2007). On the other hand, low income residents face increased economic constraints and are more likely to prioritize the cost of rent and transportation access over environmental resources (Hernandez, Collins, Grineski 2015). In addition, socially vulnerable groups may have less knowledge of the harmful effects of toxic facilities, and thus are less likely to consider these costs when making residential decisions (Zhang 2010). Further, when high polluting facilities move into neighborhoods, those that prioritize environmental resources over rent costs move out and those that prioritize rent costs over environmental resources move in, resulting in neighborhood change (Tiebout 1956; Richardson, Shortt and Mitchell 2010). While industrial actors may not intend to target socially vulnerable communities, rational economic processes result in disparate environmental impacts. From this perspective, economic, political capacity, and cultural variables should be significant predictors of exposure, while race should not.

3.2.2 A Political Action Explanation of Environmental Inequality

Environmental inequality may also occur because socially vulnerable communities have lower capacities to politically resist exposure (Mohai and Bryant 1992; Pellow 2000; Pellow, Weinberg and Schnaiberg 2001). Whereas "not in my backyard" movements have kept high-polluting facilities out of middle- and upper-class residential areas, out of perceived job growth, heavy polluting organizations are often encouraged by the state and community organizations to move into low-income areas (Pellow et al. 2001). In short, while communities with more economic, social and political capital are able to organize and resist heavy polluting organizations, communities with less social capital have less organizational and political capacity to do so (Pellow 2000). From this perspective, cultural and political capacity variables should be the primary significant predictors of exposure.

3.2.3 A Pure Discrimination Explanation of Environmental Inequality

Finally, environmental inequality may be the result of pure discrimination. Research has found that minority neighborhoods in comparison to white neighborhoods of similar income, experience higher levels of toxic exposure (Downey and Hawkins 2008). The reasoning behind this finding is that, due to racism, corporate leaders target minority communities by placing high-polluting facilities in these neighborhoods, regardless of potential economic and political costs (Pulido 2000; Rinquist 2005). From this perspective, race should be a significant predictor of residential exposure to toxic emissions, regardless of community class, cultural, and political status.

3.2.4 Summary of Environmental Inequality Theoretical Perspectives

There are three key approaches to explaining why particular communities are disproportionately exposed to industrial hazards: the economic explanation, the political action explanation and a pure discrimination explanation. The economic model views businesses and residents as rational economic actors; the environmental pollution from industrial production is dumped upon communities with less income due to market processes. The political action model focuses on structural power and conflict between businesses and residents; environmental pollution is dumped on socially vulnerable communities because they do not have the power to resist. The pure discrimination model focuses on how decision-makers will enact their bias and choose to dump pollution on minority communities. Depending on the methodological and analytical framework, there is empirical support for each of the different theoretical models. As such, theoretical and methodological debates are ongoing. For a more detailed description of methodological debates, see *Appendix A.*

3.3 The Communities Most Affected by Texas Oil and Gas Flaring and Venting

This study examines which types of communities were disproportionately exposed to Texas oil and gas extraction facility venting and flaring volumes in 2012. As you can see from *Figure 4*, communities in specific areas in the Eagle Ford and Permian Basin are disproportionately affected. This research relies on electronically metered venting and flaring volumes reported to the Texas Railroad Commission in the monthly production report in 2012 and demographic estimates from the American Community Survey to determine the relationship between the characteristics of communities surrounding facilities to facility venting and flaring volumes. My analysis focuses primarily on the characteristics of communities living in areas within 1 mile of oil and gas wells producing in Texas in 2012. Communities are defined using the Census block group as the unit of analysis. *Table 1* provides a description of how variables were measured at the community (i.e., block group), and facility level. *Table 2* involves regression results to determine the relationship between community characteristics and venting and flaring volumes. For a deeper explanation of my methodological approach, see *Appendix B.*

Figure 4. Texas Oil and Gas Extraction Facility Venting and Flaring Volumes in 2012

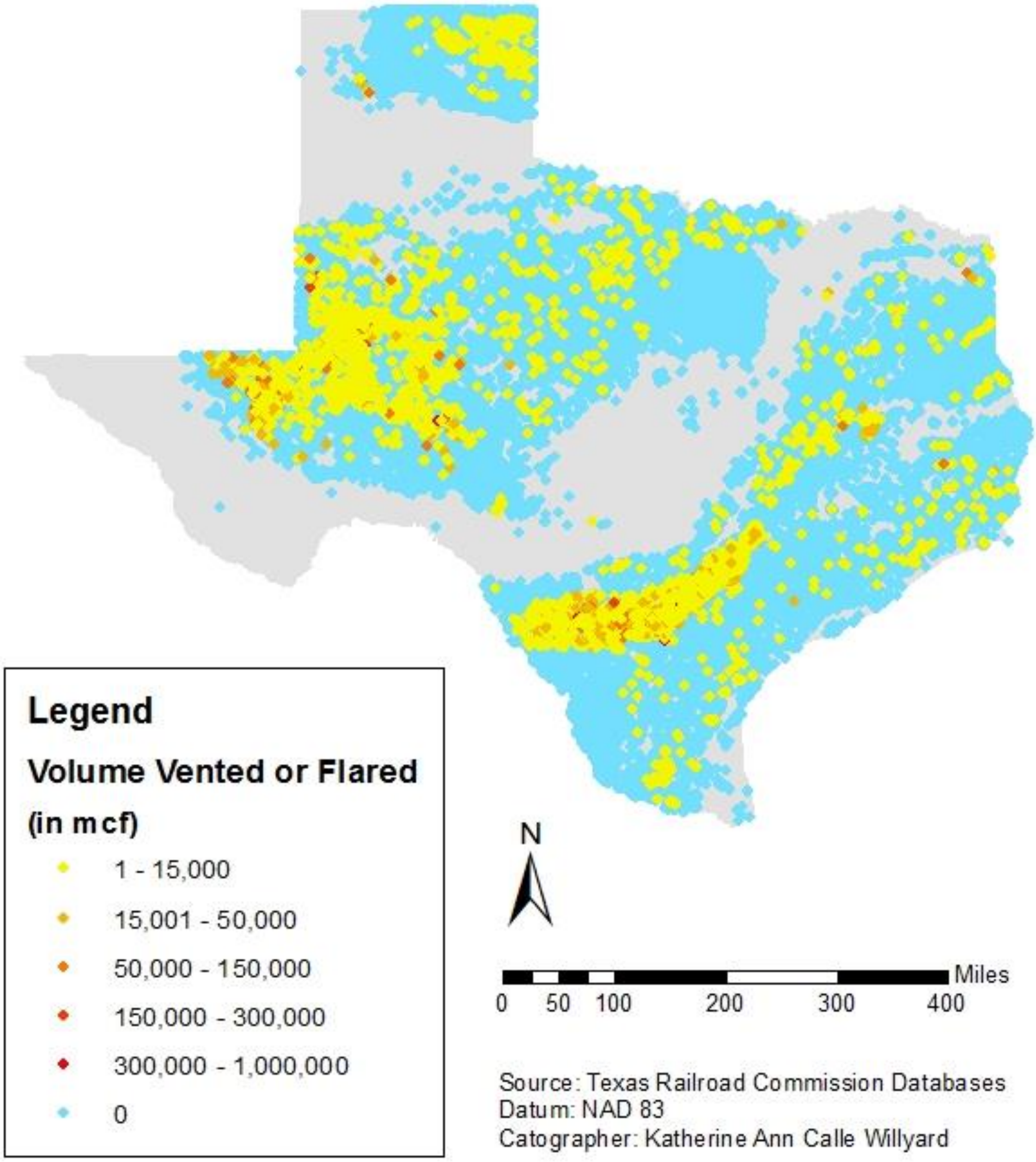


Table 1. Variables and Measures for Analysis

Variable	Facility Level Measure	Community Level Measure
Dependent Variable		
Venting and Flaring Magnitude	Volume (in mcf) of gas vented or flared at facility	Volume (in mcf) of gas vented or flared at facilities within one mile
Economic Inequality Variables		
Income	Median ACS income category[3] of households in block groups within one mile of facility	Median ACS household income category[3] of block group
Home Value	Median ACS home value category[3] of households	Median ACS home value category[3] of block group
Portion in Poverty	100 * Households in poverty in block groups within one mile of the facility / Households	100 * Household living at or below the poverty line in block group / Households
Political and Cultural Inequality Variables		
Portion Uneducated	100 * Individuals 25 and older without a high school diploma living in a block group within one mile of the facility / Individuals	100 * Individuals 25 and older without a high school diploma living in block group / Individuals 25 and older residing in block group
Portion Non-English Speaking	100 * Households with limited English fluency in block groups within one mile of the facility / Households	100 * Households with limited English fluency in block group / Households
Population Density	Individuals living in block groups within one mile of the facility / Land area of block groups within a mile of the facility (in square miles)	Individuals living in block group / Landed area of block group (in square miles)
Nonprofit Organizations	Registered nonprofits in the county in which the facility is located	Registered nonprofits in the county in which the block group is located
Racial Inequality Variables		
Portion Black	100 * Non-Hispanic black individuals residing in block groups within one mile of the facility / Individuals	100 * Non-Hispanic black individuals living in block group / Individuals
Portion Hispanic	100 * Hispanic individuals residing in block groups within one mile of the facility / Individuals	100 * Hispanic individuals living in block group / Individuals
Portion Other	100 * Individuals residing in block groups within one mile of the facility that are a race other than black, white or Hispanic / Individuals	100 * Individuals living in block group that are a race other than black, white or Hispanic / Individuals

[3] See Appendix B for list of categories.

Table 2. Zero-Inflated Negative Binomial Regression Model Results

	Facility Level Model		Community Level Model	
	b	SE	b	SE
Magnitude Model (Predicting Volume)				
Economic Inequality Variables				
Income	-.102***	0.028	0.101	0.060
Home Value	-.012	0.016	0.008	0.044
Portion in Poverty	-.032***	.006	-.042**	0.012
Political and Cultural Inequality Variables				
Portion Uneducated	-.014**	0.005	0.015	0.016
Portion Non-English Speaking	-.030***	0.008	0.040	0.027
Population Density	-.001	0.001	$-1.7\text{x}10^{-4}$*	$7.1\text{x}10^{-5}$
Nonprofit Organizations	$-1.6\text{x}10^{-4}$**	5.3x10	$-1.6\text{x}10^{-4}$***	$4.3\text{x}10^{-5}$
Racial Inequality Variables				
Portion Black	0.025**	0.009	0.002	0.011
Portion Hispanic	0.028***	0.004	0.018*	0.009
Portion Other	0.031**	0.009	0.058*	0.026
Constant	9.297***	0.373	9.211***	0.818
Inflation Model (Predicting Zeros)				
Economic Inequality Variables				
Income	-.070***	0.010	-.098***	0.026
Home Value	-.037***	0.006	0.130***	0.015
Portion in Poverty	0.051***	0.002	0.012**	0.005
Political and Cultural Inequality Variables				
Portion Uneducated	-.030***	0.002	-.013*	0.005
Portion Non-English Speaking	-.025***	0.003	-.001	0.006
Population Density	0.002***	$3.2\text{x}10^{-4}$	0.001***	$3.6\text{x}10^{-5}$
Nonprofit Organizations	$2.1\text{x}10^{-4}$***	$3.8\text{x}10^{-5}$	$7.7\text{x}10^{-5}$***	$1.6\text{x}10^{-5}$
Racial Inequality Variables				
Portion Black	0.018***	0.003	.017***	.004
Portion Hispanic	-.021***	0.001	0.004	0.002
Portion Other	-.050***	0.004	0.025**	0.010
Constant	4.317***	0.133	0.175	0.316
Ln Alpha	2.325***	0.054	2.381***	0.101
Alpha	10.228	0.551	10.813	1.088
N	126,861		15,729	
Adjusted R^2	0.030		0.061	
LR $Chi^2(10)$	200.34		102.26	
AIC	1.251		1.368	
AIC*n	158,747.288		21,520.137	

*** p<0.001 ** p<0.01 * p<0.05 (two-tailed significance tests)

3.3.1 Economic Class and Venting and Flaring Exposure

If a resident owns mineral rights, they receive royalty payments for the oil extracted along with the flared natural gas. This “mailbox money” is a financial miracle for these rural residents (Tedesco and Hiller 2014). As such, these payments mitigate conflict between residents and polluting facility operators, making the community more tolerant of the health hazards being produced. Findings show that communities most exposed to venting and flaring experience lower levels of economic disenfranchisement. These findings directly oppose an economic explanation hypothesis of environmental inequality. While there is ample evidence that the communities exposed to venting and flaring face less economic disenfranchisement in the form of lower levels of poverty, the effect on income and household home values is less consistent.

While facilities located in higher income communities are significantly more likely to vent or flare, among producing Texas oil and gas extraction facilities that vented or flared in 2012, facilities located in higher income communities vent and flare significantly less gas than facilities located in lower income communities. Among facilities that vented or flared, if a facility were to increase the median income level of households living in block groups within one mile of the facility by one category, the expected volume of gas vented or flared at the facility would decrease by 10% while holding all other variables in the model constant. While there is a significant negative relationship between community income and venting and flaring volumes, there is a significant positive relationship between surrounding community income and the likelihood a facility vented or flared. Among all producing oil and gas extraction facilities in 2012, if a facility were to increase the surrounding community median household income level by one category, the expected likelihood that the facility did not vent or flare in 2012 decreases by 7% while holding all other variables in the model constant, and this relationship is statistically significant.

Among all Texas communities, those with higher incomes are more likely to be located near a venting and flaring facility. Among all communities, if the median income level of households were to increase by one category, the odds that the community is within one mile of a facility that vented or flared in 2012 decreases by a factor of 9% while holding all other variables in the model constant, and this relationship is statistically significant. However, there is no significant relationship between the characteristics of communities within one mile of a venting or flaring well and community exposure to venting and flaring volumes.

While facilities located in communities with higher home values are significantly more likely to vent and flare than those in communities with lower income values, there is no significant association between home values and venting and flaring volumes. Among producing Texas oil and gas extraction facilities that vented or flared in 2012, when controlling for other factors, the higher the surrounding community median owner-occupied housing value level, the lower predicted volume of gas vented or flared, but this relationship is not statistically significant. On the other hand, among all producing Texas oil and gas facilities, if a facility were to increase the median owner-occupied housing value level of block groups within one mile by one category, the odds that the facility did not vent or flare in 2012 decreases by 4% while holding all other variables in the model constant, and this relationship is statistically significant.

Whereas when examining variation between facilities there is a significant positive relationship between home values and venting/flaring likelihoods, when examining variation between communities, there is a significant negative relationship. Among all Texas communities, if a community were to increase the median owner-occupied housing value category by one, the odds that the community would be not be within one mile of a facility that vented or flared increases by 14% while holding all other variables in the model constant, and this relationship is statistically significant. Among all Texas communities within one mile of a facility that vented or flared in 2012, when controlling for other factors, the higher the surrounding community owner-occupied housing value level, the fewer predicted volume of gas vented or flared, but this relationship is not statistically significant.

Results consistently show a negative correlation between poverty levels and venting and flaring practices. Facilities located in communities with a lower portion of the community living in poverty are both more likely to vent or flare and vent or flare at higher rates than facilities located in poorer communities. Among producing Texas oil and gas extraction facilities that vented or flared in 2012, when controlling for other factors, the higher the surrounding community portion living at or below the poverty line, the smaller predicted volume of gas vented or flared, and this relationship is statistically significant. Among facilities that vented or flared, if a facility were to increase the portion of households surrounding the facility living at or below the poverty line by 1%, the expected volume of gas vented or flared at the facility would decrease 3% while holding all other variables in the model constant. Likewise, there is a significant positive relationship between the portion of the surrounding community living in poverty and the likelihood a facility vented or flared. Among all producing oil and gas extraction facilities in 2012, if a facility were to increase the proportion of surrounding community households living at or below the poverty line by 1%, the expected likelihood that the facility did not vent or flare in 2012 increases by 5% while holding all other variables in the model constant, and this relationship is statistically significant.

Furthermore, communities with a higher portion of residents living in poverty are both significantly less likely to be within a mile of venting and flaring facilities and experience significantly lower volumes. Among communities within one mile of an oil and gas extraction facility that vented or flared in 2012, if the proportion of households living at or below the poverty line were to increase by one, the expected volume of gas vented or flared at facilities within one mile of the block group would decrease by 4% while holding all other variables in the model constant, and this relationship is statistically significant. Among all communities, if the portion of households living at or below the poverty line were to increase by 1%, the odds that the block groups is not within one mile of a facility that vented or flared in 2012 increases by a 1% while holding all other variables in the model constant, and this relationship is statistically significant.

Depending on the unit of analysis, there are different effects of economic class on exposure to venting and flaring practices. Regardless, results allude to economic trade-offs to community exposure to venting and flaring. These findings directly contradict economic explanations of environmental inequality. Among oil and gas extraction facilities that vent or flare, venting and flaring practices are related to lower surrounding community incomes, and a lower portion of surrounding residents living at or below the poverty line. Among all oil and gas extraction facilities, engagement in venting and flaring is most likely among facilities with surrounding communities that have higher incomes, higher home values, and a lower portion of households living at or below the poverty line. Among communities within one mile of facilities that vent or flare, venting and flaring practices are related to higher household incomes and a lower portion of households living at or below the poverty line. Among all communities, engagement in venting and flaring is most likely among communities with higher household incomes, lower home values, and a lower portion of households living at or below the poverty line. A common thread is that there is a significant negative correlation with community exposure to venting and flaring volumes and the portion of surrounding households living at or below the poverty. Those who are disproportionately affected by venting and flaring practices of the oil and gas extraction industry face lower levels of poverty. This suggests there are economic tradeoffs for a community to subject itself to venting and flaring practices.

3.3.2 Political and Cultural Capital and Venting and Flaring Exposure

There is little evidence that communities with less cultural capital are disproportionately exposed to venting and flaring. While facilities in less educated communities are more likely to vent or flare, venting and flaring volumes for facilities that vented or flared are greater for facilities in more educated communities. Among producing Texas oil and gas extraction facilities that vented or flared in 2012, when controlling for other factors, the higher the surrounding community portion without a high school diploma, the fewer predicted volume of gas vented or flared, and this relationship is statistically significant. Among facilities that vented or flared, if a facility were to increase the potion of residents 25 and older without a high school diploma in block groups within one mile of the facility by 1%, the expected volume of gas vented or flared at the facility would decrease by almost 2% while holding all other variables in the model constant. Among all producing oil and gas extraction facilities in 2012, if a facility were to increase the portion of surrounding community residents 25 and older without a high school diploma by 1%, the expected likelihood that the facility did not vent or flare in 2012 decreases by 3% while holding all other variables in the model constant, and this relationship is also statistically significant.

Less educated communities are significantly more likely to be within a mile of a venting/flaring facility, yet there is no significant relationship between community education and venting/flaring volumes. Among all communities, if the portion of residents 25 and older without a high school education were to increase by 1% the odds that the community is not within one mile of a facility that vented or flared in 2012 decreases by 1% while holding all other variables in the model constant, and this relationship is statistically significant. On the other hand, among communities within a mile of a venting/flaring facility, there is no significant relationship between community education levels and the volume of gas vented or flared.

When examining venting and flaring variation at the community level, there is no significant relationship between English fluency and venting and flaring practice. However, there is a significant, but inconsistent, relationship between English fluency and exposure to venting and flaring at the facility-level. Facilities located in communities with greater portion of residents with limited English language fluency are more likely to vent or flare, yet venting/flaring facilities located in communities with a greater portion of residents with limited English language vent and flare significantly less gas. Among facilities that vented or flared, if a facility were to increase the potion of households with limited English fluency in communities within one mile of the facility by 1%, the expected volume of gas vented or flared at the facility would decrease by 3% while holding all other variables in the model constant. Among all producing oil and gas extraction facilities in 2012, if a facility were to increase the portion of surrounding community households with limited English language fluency by 1%, the expected likelihood that the facility did not vent or flare in 2012 decreases by a factor of 3% while holding all other variables in the model constant, and this relationship is statistically significant.

In sum, the effect of community cultural capital on disproportionate venting and flaring volumes is not clear. Facilities surrounded by communities with less cultural capital are more likely to vent or flare, yet among the communities surrounding facilities that do vent or flare, facilities surrounded by communities with more cultural capital vent or flare more. While there is a significant relationship between cultural capital and exposure when examining variation at the facility-level, there is no significant relationship when examining communities.

Communities with few organizational capacities lack the social resources to resist exposure to incoming high polluting industrial facilities. There are fewer risks associated with organizing heavy polluting industrial activities in less populated areas and those areas with fewer nonprofit organizations that provide residents with greater social organizational capacities to legally resist polluting facilities. Results show that communities with less political organizational capacities are disproportionately exposed to venting and flaring.

While surrounding population density is not a significant factor predicting facility venting and flaring volumes, there is a significant negative relationship between surrounding community population density and whether or not the facility vented or flared- facilities in less dense communities are significantly more likely to engage in venting or flaring. Among all producing oil and gas extraction facilities in 2012, if a facility were to increase the surrounding community population density by one person per square mile, the expected likelihood that the facility did not vent or flare in 2012 increases by 0.2% while holding all other variables in the model constant. In other words, facilities surrounded by communities with more people per square mile are less likely to vent or flare.

When examining all Texas communities, there is a consistent significant positive correlation between venting and flaring and the population density of the community. Among communities within one mile of an oil and gas extraction facility that vented or flared in 2012, if the people per square mile were to increase by one, the expected volume of gas vented or flared at facilities within one mile of the community would decrease by 0.02% while holding all other variables in the model constant, and this relationship is statistically significant. Among all communities, if the people per square mile were to increase by 1%, the odds that the community is not within one mile of a facility that vented or flared in 2012 increases by 0.1% while holding all other variables in the model constant, and this relationship is statistically significant. In short, communities with more people per square mile are less likely to be near a venting or flaring facility and those that are near a venting and flaring facility experience lower venting and flaring volumes.

There is a significant negative correlation between facility venting and flaring practices and the number of nonprofits in the county in which the facility is located. Among producing Texas oil and gas extraction facilities that vented or flared in 2012, when controlling for other factors, the greater number of registered nonprofits in the county in which the facility is located, the fewer predicted volume of gas vented or flared, and this relationship is statistically significant. Among facilities that vented or flared, if a facility were to be in a county with one more registered nonprofit organization, the expected volume of gas vented or flared at the facility would decrease by 0.02% while holding all other variables in the model constant. Furthermore, among all producing oil and gas extraction facilities in 2012, if a facility were to increase the number of nonprofits in the county in which the facility is located by one, the expected likelihood that the facility did not vent or flare in 2012 increases by 0.02% while holding all other variables in the model constant, and this relationship is statistically significant. In other words, facility venting and flaring practices are more likely and greater in counties with fewer registered nonprofit organization.

Like facility-level findings, community-level findings a significant relationship between venting and flaring engagement and volumes and the number of nonprofit organizations registered in the county in which the community is located. Among communities within one mile of an oil and gas extraction facility that vented or flared in 2012, if the number of registered nonprofit organizations in the county were to increase by one, the expected volume of gas vented or flared at facilities within one mile of the block group would decrease by 0.02% while holding all other variables in the model constant, and this relationship is statistically significant. Among all communities, if the number of nonprofits in the county were to increase by one, the odds that the block groups is not within one mile of a facility that vented or flared in 2012 increases by 2% while holding all other variables in the model constant, and this relationship is statistically significant. In short, communities in counties with more nonprofit organizations are less likely to be near a venting or flaring facility and those that are near a venting and flaring facility experience lower venting and flaring volumes.

Communities and facilities in counties with fewer nonprofit organizations were disproportionately exposed to oil and gas extraction facility venting and flaring practices in 2012. Additionally, less dense communities experience greater venting and flaring volumes and are more likely to be near a facility that vented or flared. On the other hand, while the effect of surrounding community population density is a significant predictor of whether the facility engages in venting and flaring, it is not a significant predictor of venting and flaring volumes. These findings demonstrate that communities with less political organizational capacities are disproportionately exposed to venting and flaring practices. Furthermore, facilities are more likely to vent or flare when there are fewer people surrounding the facility. This supports the idea that communities with greater organizational capacities are more likely to resist exposure and facility operators are more likely to engage in venting and flaring in areas where there are less political risks for doing so.

3.3.3 Race and Venting and Flaring Exposure

Particular racial groups are disproportionately exposed to oil and gas extraction facility venting and flaring practices. Findings show that Hispanic communities are more affected by venting and flaring at Texas oil and gas extraction facilities.

While facilities that vent or flare are less likely to be surrounded by communities with a higher portion of black residents, among venting and flaring facilities, those surrounded by a community with a higher portion of black residents vent and flare more gas. Among producing Texas oil and gas extraction facilities that vented or flared in 2012, when controlling for other factors, the higher the surrounding community portion of black residents, the greater predicted volume of gas vented or flared, and this relationship is statistically significant. Among facilities that vented or flared, if a facility were to increase the portion of black residents in communities within one mile of the facility by 1%, the expected volume of gas vented or flared at the facility would increase by 3% while holding all other variables in the model constant. However, there is a significant negative relationship between black communities and the likelihood a facility vented or flared. Among all producing oil and gas extraction facilities in 2012, if a facility were to increase the portion of black residents in surrounding communities by 1%, the expected likelihood that the facility did not vent or flare in 2012 increases by a factor of 2% while holding all other variables in the model constant, and this relationship is statistically significant.

On the other hand, while communities with a greater portion of black residents are significantly less likely to be near a facility that vented or flared, there is no significant relationship between the portion of residents that are black in the community and the venting and flaring volume of surrounding facilities. Among all communities, if the portion of black residents were to increase by 1%, the odds that the community is not within one mile of a facility that vented or flared in 2012 increases by 2% while holding all other variables in the model constant, and this relationship is statistically significant.

Results consistently show Hispanic residents are disproportionately exposed to venting and flaring practices. Facilities surrounded by a greater portion of Hispanic residents are both significantly more likely to vent or flare and vent or flare a greater amount. Among producing Texas oil and gas extraction facilities that vented or flared in 2012, when controlling for other factors, the higher the surrounding community portion of Hispanic residents, the greater predicted volume of gas vented or flared, and this relationship is statistically significant. Among facilities that vented or flared, if a facility were to increase the portion of Hispanic residents in surrounding communities by 1%, the expected volume of gas vented or flared at the facility would increase by 3% while holding all other variables in the model constant. Likewise, among all producing oil and gas extraction facilities in 2012, if a facility were to increase the portion of Hispanic residents in communities within one mile by 1%, the expected likelihood that the facility did not vent or flare in 2012 decreases by 2% while holding all other variables in the model constant, and this relationship is statistically significant.

On the other hand, while communities with a greater portion of Hispanic residents experience significantly more venting and flaring volumes, there is no significant relationship between the portion of residents that are Hispanic in the community and the likelihood that the community is within one mile of the facility that vented or flared. Among neighborhoods within one mile of an oil and gas extraction facility that vented or flared in 2012, if the portion of Hispanic residents were to increase by 1%, the expected volume of gas vented or flared at facilities within one mile would increase by 2% while holding all other variables in the model constant, and this relationship is statistically significant.

There is also a significant relationship between the portion of the community that is some race other than black, white or Hispanic and venting and flaring volumes. At both the facility community level, there is a significant positive relationship between venting and flaring volumes and the portion of the community that is some other race. Among facilities that vented or flared, if a facility were to increase the portion of residents that are some other race in communities within one mile of the facility by 1%, the expected volume of gas vented or flared at the facility would increase by 3% while holding all other variables in the model constant. Likewise, among all producing oil and gas extraction facilities in 2012, if a facility were to increase the portion of other race residents in communities within one mile by 1%, the expected likelihood that the facility did not vent or flare in 2012 decreases by 5% while holding all other variables in the model constant, and this relationship is statistically significant.

While there is a consistent positive relationship between the portion of the community that is some other race and venting and flaring volumes at the facility level, the relationship is less consistent at the level of the community. Among neighborhoods within one mile of an oil and gas extraction facility that vented or flared in 2012, if the portion of other race residents were to increase by 1%, the expected volume of gas vented or flared at facilities within one mile would increase by 6% while holding all other variables in the model constant, and this relationship is statistically significant. On the other hand, among all communities, if the portion of other race residents were to increase by 1%, the odds that the community is not within one mile of a facility that vented or flared in 2012 increases by 3% while holding all other variables in the model constant, and this relationship is statistically significant.

In sum, due to contradictory findings, there is limited support for the environmental racism hypothesis. While communities with a greater portion of Hispanic residents experience significantly higher venting and flaring volumes from surrounding facilities, there is no significant relationship between the portion of Hispanic residents and the likelihood the community is within one mile of a facility. Also, while communities with a greater portion of black residents are significantly less likely to be within one mile of a facility that vents or flare, there is no significant relationship between the portion of black residents in a community and venting and flaring volumes. However, when focusing on facilities, there is more evidence of the environmental hypothesis. Facilities surrounded by communities with a greater portion of Hispanic residents are both more likely to vent or flare and vent or flare more gas. Furthermore, venting and flaring facilities surrounded by communities with a greater portion of black residents vent or flare significantly more than communities with a lower portion of black residents.

3.4 An Overview of Environmental Equity Issues

Findings demonstrate that when predicting variation in venting and flaring volumes, different units of analysis result in different findings. However, due to consistent findings that low poverty and less organized communities are disproportionately exposed to venting and flaring volumes, results provide the greatest support for the political action explanation of political inequality.

Texas oil and gas extraction facilities that vent or flare more gas are significantly more likely to be surrounded by communities with higher incomes, less poverty, less political power, and a higher portion of minority residents. Furthermore, facilities with higher incomes, lower housing values, less poverty, less education, less political power, a higher portion of other race residents, and a lower portion of black residents are significantly more likely to engage in venting or flaring.

On the other hand, focusing on the community, rather than the facility leads to different results. Communities that experience greater venting and flaring volumes are more likely to have lower incomes, less poverty, less cultural capital, less political power, and a higher portion of Hispanic and other race residents. Also, communities with less economic capital, less cultural capital, less political power, a higher portion of black or other race residents are significantly more likely to be within one mile of a facility that vented or flare.

In comparison to economic and pure discrimination explanations of environmental inequality, these finding fall more in line with a political action hypothesis; because facility operators weigh political costs when deciding whether or not to invest in technologies necessary to capture gas that is otherwise vented or flared, the political power of communities surrounding oil and gas extraction facility is a key predictor of facility venting and flaring volumes. A consistent factor predicting venting and flaring practices is the political power of affected communities. Political capital has a significant negative relationship with facility venting and flaring volumes at both the facility and community level.

In conclusion, it is important to focus on variation between facilities, not just on variation between communities, so we can better understand why some facilities are more likely to have cleaner operations than others. This is the focus of the next section.

4. SOCIAL PROCESSES UNDERLYING FLARING AND VENTING

> “The ultimate goal is to reduce flaring as much as possible and capture the gas in our wells.” (Russel Rankin 2012)

Venting and flaring extracted natural gas is not usually necessary. There are technical solutions available to eliminate routine venting and flaring. Companies sell and rent small-scale gas to liquids technologies to bring extracted gas to the market regardless of the location, but only some companies choose to minimize venting and flaring by investing in these green technologies. For example, to minimize venting and flaring in remote areas in North Dakota, Statoil has invested in technologies to store and use natural gas. Many other companies have committed to investing in these green technologies to eliminate routine flaring by 2030, regardless of facility remoteness (World Bank 2016). However, not all companies are equally committed to these green investments. This section explores how variation in the organizational and political characteristics of the facility and the company that operates the facility (i.e., operators) relate to variations in venting and flaring outcomes.

4.1 The “Double Diversion” Supporting Ecological Inefficiency

Rural sociologists have identified how environmental degradation is supported by a "double diversion" (Freudenburg 2006). The first part of the “double diversion” is how environmental resources are diverted to privileged groups. There is a prevalent myth that environmental degradation is assumed to be a uniform activity routinely practiced by all.

However, in reality, a few outliers are responsible for most industrial pollution emissions. In a quantitative analysis of industrial pollution from 1854-2010, Heede (2014) found that two-thirds of the world's industrial carbon dioxide and methane emissions came from just 90 large companies. Likewise, a small number of facilities and operators are responsible for the Texas oil and gas industry's venting and flaring emissions. In 2012, among the 170,245 producing oil and gas extraction facilities directly controlled by 4,425 different operators, only 487 different operators (9.91%) engaged in venting and flaring at 7,632 (4.48%) facilities.

The second part of the "double diversion" is the diversion of narratives such that environmental degradation is assumed to be mostly necessary for industrial productivity (Freudenburg 2006). Even when controlling for productivity, some types of facilities are disproportionately responsible for heavy pollution (Grant et. al. 2002; Grant and Jones 2003; Grant and Jones 2004: Grant et. al. 2010). Likewise, venting and flaring practices are not necessary for industrial productivity. Even when controlling for productivity, some types of facilities and operators are disproportionately responsible for venting and flaring.

Prior research on disproportionality examines which types of organizations are disproportionately responsible for heavy pollution in urban areas. Facilities disproportionately responsible for environmental degradation tend to be large (Grant et. al. 2002), subsidiary organizations, meaning they are organizations with more than 50% of the stock owned by a legally separate corporation (Grant and Jones 2003), and are primarily located in poor, minority neighborhoods (Grant et.al. 2004; Grant et.al. 2010, Collins, Munoz and JaJa 2016). Furthermore, heavy polluting organizations are affected by resource dependence (Prechel and Zheng 2012; Prechel and Touche 2014), corporate structure (Prechel and Istvan 2016; Prechel and Touche 2014; Prechel and Zheng 2012), and firm political embeddedness (Prechel and

Zheng 2012; Prechel and Touche 2014; Prechel and Istvan 2016). By revealing the types of facilities that pollute at a higher rate than others, disproportionality research identifies the specific social structural factors related to high industrial pollution levels. However, disproportionality research primarily focuses on industrial pollution in urban areas. This analysis expands disproportionality research by focusing on a specific form of pollution that occurs in rural areas – venting and flaring. In line with research on disproportionality, this section identifies the types of facilities and operators most responsible for venting and flaring in Texas.

4.2 Explaining Industrial Pollution Practices as a Two-Part Process

Prior disproportionality research primarily explains variation in pollution magnitude among large industrial facilities that reports to the Environmental Protection Agency. As explained in detail in *Appendix B*, research on point emission sources in the United States primarily relies upon Environmental Protection Agency data, which omits small organizations from reporting. However, there are a significant number of small organizations within the population (Granovetter 1984). By ignoring small facilities and those that pollute little, researchers have yet to have a comprehensive understanding of the factors contributing to the environmental performance of organizations.

The environmental practices of an organization are not just about the magnitude of a polluting behavior; it is also about decisions on whether or not to engage in a polluting behavior in the first place. Furthermore, the factors contributing to decisions to engage in a polluting behavior may differ from the factors relating to pollution magnitudes. For this reason, I examine oil and gas extraction facility venting and flaring practices as a distinct two-part process. First, I examine the factors related to whether a facility engaged in venting and flaring. Then, among the facilities that vented or flared, I examine the factors related to venting and flaring rates. This method differs from the analysis in the previous section. Whereas prior analysis assumes the processes predicting whether or not a facility vents or flares is the same as the processes predicted venting and flaring volumes, this analysis assumes the processes are not similar. This allows there to be a sequential decision-making process. One set of factors can influence the decision of whether or not a facility engages in venting or flaring. Then, after the decision to vent and flare is made, another set of factors can influence venting and flaring volumes. A detailed description of my methodological approach can be found in *Appendix C*. Facility summary statistics are presented in *Table 3*. Regression results for my cross-sectional analysis are presented below in *Table 4*.

Table 3. Measures and Summary Statistics

Variable	Measure	All Facilities Mean	All Facilities S.D.	Venting/Flaring Facilities Mean	Venting/Flaring Facilities S.D.
Dependent Variables					
Venting/Flaring Facility	1- Facility Vented or Flared, 0- Not	0.036	0.185	1.0	0.0
Venting/Flaring Volume	Log(MCF of gas vented or flared)	4.97	2.83	4.97	2.87
Community Variables					
Income	Median Income of Households in Block Groups within One Mile of Facility	56,000	2,060	56,260	1,975
Home Value	Median Home Value of Homes in Block Groups within One Mile of Facility	102,000	5,187	100,200	5,494
Portion in Poverty	Same as described in Table 1	10.43	7.72	11.14	9.45
Portion Uneducated	Same as described in Table 1	X	X	X	X
Portion Non-English Speaking	Same as described in Table 1	5.44	7.06	8.48	8.40
Population Density	Same as described in Table 1	19,300	2,146	8,564	4,312
NGOs	Same as described in Table 1	344	1,080	168.8	345
Portion Black	Same as described in Table 1	3.89	8.18	1.99	5.24
Portion Hispanic	Same as described in Table 1	30.48	28.57	43.36	28.46
Portion Other	Same as described in Table 1	1.23	2.53	1.25	2.58
Facility Variables					
Permit	Facility has Permit to Legally Flare	0.01	0.11	0.10	0.30
Inspections	Facility Inspections	1.56	5.45	2.18	9.71
Oil Produced	(Barrels of Oil Produced at Facility)^2	$2.4x10^{10}$	$3.1x10^{11}$	$2.9x10^{10}$	$1.2x10^{12}$
Gas Produced	(MCF of Gas Produced at Facility)^2	$3.1x10^{10}$	$3.0x10^{12}$	$2.0x10^{11}$	$7.6x10^{12}$
Wellbores	Facility Wellbores	2.76	20.87	9.20	76.34
New Drilling	New Wellbores Drilled at Facility	0.06	0.80	0.42	2.05
Gas Wells	1- Gas Well, 0- Oil Lease	0.69	0.46	0.40	0.49
Well Density	Wellbores within One Mile of Facility	19.72	18.39	15.6	19.3
Nearest Pipe	Miles to Nearest Gas Pipeline	2.42	3.44	2.30	2.97
Operator Variables					
Oil Produced	Barrels of Oil Produced by Operator	$1.5x10^8$	$2.6x10^8$	$1.3 x10^8$	$2.1 x10^8$
Gas Produced	MCF of Gas Produced by Operator	$6.4x10^6$	$1.1x10^7$	$9.9 x10^6$	$1.2 x10^7$
Wellbores	Wells owned by Operator	3518	4479	5331	6184
Subsidiary	1- Facility is owned by subsidiary, 0- Not	0.16	0.37	0.17	0.37
Ultimate Parent	1- Facility is owned by ultimate parent, 0- Not	0.06	0.24	0.18	0.38
Interaction Variables					
Size Interaction	(MCF of Gas Produced by Facility) x (MCF of Gas Produced by Operator)	$1.2x10^{13}$	$5.19 x10^{13}$	$1.6 x10^{13}$	$8.1 x10^{13}$

X = Results Not Releasable Due to Census Confidentiality Requirements

Table 4. Flaring and Venting Hurdle Model Results

	Model 1		Model 2		Model 3		Model 4	
	VF Fac.	VF Vol.	VF Fac.	VF Vol.	VF Fac.	VF Vol.	VF Fac.	VF Vol.
Community Variables								
Income	$1x10^{-5}$***	$3x10^{-5}$***	$1x10^{-5}$***	$3x10^{-5}$***	$7x10^{-6}$	$6x10^{-6}$	$6x10^{-6}$	$8x10^{-6}$
Home Value	$9x10^{-8}$**	$4x10^{-6}$***	$9x10^{-8}$	$4x10^{-6}$	$2x10^{-6}$	$4x10^{-6}$*	$1x10^{-6}$	$1x10^{-6}$
Portion in Poverty	-.021***	-.027***	-.021	-.027	-.007	-.017	-.002	-.014
Portion Uneducated	X	X	X	X	X	X	X	X
Portion Non-English Speaking	0.022***	-.049***	0.022	-.049	0.026**	-.009	0.034**	0.005
Population Density	$-3x10^{-9}$	$1x10^{-7}$	$-3x10^{-9}$	$1x10^{-7}$***	$-5x10^{-9}$	$1x10^{-7}$***	$-3x10^{-9}$	$1x10^{-7}$
NGOs	$-4x10^{-4}$***	-.001***	$-4x10^{-4}$	-.001***	$-3x10^{-4}$	-.001***	$-2x10^{-4}$	$-4x10^{-4}$
Portion Black	-.026***	0.031***	-.026	0.031	-.027	0.024	-.023	0.27
Portion Hispanic	0.011***	0.018***	0.011	0.018	0.015	0.015	0.013	0.13
Portion Other	0.034***	-.060***	0.034	-.060	0.039	-.003	0.047	-.008
Facility Variables								
Permit					1.925***	1.66***	1.955***	1.786***
Inspections					-.006	0.003	-.003	0.005
Oil Produced					$-5x10^{-14}$	$-2x10^{-13}$***	$-2x10^{-14}$	$-2x10^{-12}$***
Gas Produced					$4x10^{-15}$	$1x10^{-14}$***	$-2x10^{-15}$	$6x10^{-15}$
Wellbores					0.001	0.002	$3x10^{-4}$	0.002*
New Drilling					0.117**	0.204***	.100**	0.147***
Gas Wells					-1.24*	-2.387***	-1.272*	-.195***
Well Density					0.003	-.011	-.007	-.010
Nearest Pipe					-.042**	-.124***	-.031*	0.096***
Operator Variables								
Oil Produced							$-1x10^{-9}$	$6x10^{-8}$***
Gas Produced							$-7x10^{-10}$	$-1x10^{-9}$
Wellbores							$9x10^{-5}$**	$-1x10^{-4}$
Subsidiary							-.002	1.100*
Ultimate Parent							0.909	0.054
Interaction Variables								
Size Interaction							$2x10^{-15}$	$2x10^{-15}$**
Constant	-4.784***	0.879***	-4.784***	0.879***	-3.863***	3.831***	-7.067***	3.584***
~N	150,000	5,500	150,000	5,500	150,000	5,500	150,000	5,500
~Clusters	N/A	N/A	4,700	400	4,700	400	4,700	400
Pseudo R^2	0.042	0.122	0.042	0.122	0.115	0.390	0.152	0.446

X = Results Not Releasable Due to Census Confidentiality Requirements *** p<0.001 ** p<0.01 * p<0.05 (two-tailed significance tests)

4.3 The Structural Factors Related to Venting and Flaring

4.3.1. Community Embeddedness

Model 1 shows results of a hurdle regression model using only community characteristics, and without accounting for the similarities of facilities controlled by the same operating company. These results are similar to facility-level findings presented in the previous chapter. For example, the significant predictors of whether a facility vents or flares presented in Model 1 are the same as those presented in the previous chapter. However, there are several differences. While income has a positive significant relationship between venting and flaring volumes in Model 1, the relationship between venting and flaring volumes and income was negative in the previous chapter. Also, while the portion of the surrounding community that is some race other than black, Hispanic, or white has a significant negative relationship with venting and flaring volumes in Model 1, the relationship between venting and flaring volumes and the portion of the surrounding community that is some other race was positive in the previous chapter. These differences emerge for two reasons. First of all, Model 1 explains venting and flaring as a two-part process. Second, Model 1 involved the use of restricted Census data to better quantify the characteristics of remote communities. Findings from Model 1 provide further support for the theory that there are economic tradeoffs for a community to subject itself to venting and flaring practices. Because facilities that vent and flare more are associated with higher incomes, higher home values, and lower poverty levels, surrounding residents may be more willing to accept heavy venting and flaring practices.

Model 2 is like Model 1, but Model 2 accounts for the similarities of facilities controlled by the same operating company. Results show that once these similarities are accounted for, few community characteristics are significant predictors of venting and flaring practices. For example, the only significant predictor of whether or not a facility engages in venting and flaring is the household income of surrounding communities; facilities in areas where residents have higher incomes are more likely to vent or flare than facilities in areas with lower incomes. There are several significant community predictors of facility venting and flaring volumes. Results show communities with higher incomes, higher population densities and fewer registered nonprofit organizations have significantly higher venting and flaring volumes. However, as demonstrated by Pseudo R^2s of less than 0.15, Model 2 accounts for a small amount of variation in venting and flaring practices.

Like Model 2, Model 3 and Model 4 both account for similarities of facilities controlled by the same operating company. However, Model 3 controls for facility-level predictors and Model 4 controls for both facility and operator-level predictors. As demonstrated by Pseudo R^2s ranging from 0.390 to 0.446, these model account for a much larger variation in venting and flaring volumes than Model 2. Results show that once both facility and operator characteristics are accounted for, there is no relationship between community characteristics and venting and flaring volumes. Furthermore, the only significant predictor of whether or not a facility vents or flares is the potion of non-English speakers surrounding the facility. For each percent increase in the portion of residents surrounding the facility that speak little to no English, the estimated odds that the facility vented or flared increases by 3%, regardless of other facility and operator factors, and this relationship is statistically significant.

In short, when controlling for facility and operator-level factors, community embeddedness has a significant effect on facility participation in venting and flaring practices, but it does not influence the extent to which the facility vents or flares. Facilities surrounded by communities with a higher portion of non-English speaking residents are more likely to vent and flare than facilities surrounded by communities with a lower portion of non-English speaking residents. This suggests the cultural capital of communities surrounding a facility is associated with whether or not the surrounding community is exposed to venting and flaring, but not the extent to which the community is exposed.

4.3.2. Regulatory Embeddedness

Results show that regulatory embeddedness is a factor associated with facility venting and flaring practices. Permitting is associated with both facility participation in venting and flaring practices and the extent to which the facility vents or flares, but state inspections is not. State permitting of venting and flaring is related to the venting and flaring practices of facilities, even when controlling for other community, operator, and facility-level factors. As shown in Model 4, the estimated odds that a facility that received a permit to legally vent or flare vents or flares is 7 times greater than the corresponding odds for a facility that did not receive a permit, regardless of other facility, community and operator factors and this relationship is statistically significant. Similarly, among venting and flaring facilities, the venting and flaring volumes of facilities that received a permit to legally vent or flare are about 6 times greater than the corresponding venting and flaring volumes of facilities that did not receive a permit to legally vent or flare. However, there is no significant relationship between inspections and facility venting and flaring practices. By providing companies with legal opportunities to vent or flare, state permits allow for extreme venting and flaring. However, inspections do little to deter venting and flaring. In line with arguments made in section 2, this suggests that state policy provides ample opportunities and few disincentives to vent or flare natural gas.

4.3.3. Size

Size has a significant, but inconsistent, effect on venting and flaring. As shown in Model 4, while there is no direct relationship between the volume of gas produced and facility venting and flaring practices, there is an inconsistent significant effect between the volume of oil produced by facilities and operators. Facilities that produce more oil are less likely to vent or flare and they vent and flare less extensively than those that produce less oil. However, operators that produce more oil vent and flare more extensively than those that produce less oil. This suggests that the effect of organizational inertia on environmental degradation emerges at the operator-level. Because large oil production companies are likely to have more employees, more hierarchical layers, and more political and economic power, they are less responsive to changes in technology. However, further research using restricted business data is needed to further explore the relationship between size and venting and flaring practices.

While there is no main effect of facility and operator gas production on venting and flaring volumes, there is a significant interaction effect. High gas production facilities operated by companies that produce more gas vent and flare more than smaller gas production facilities operated by companies that produce less gas. This contradicts my original hypothesis that large gas producers are more likely to use green completion equipment on their high producing facilities. Future research should further explore why small gas production companies vent and flare less gas at facilities that produce less.

4.3.4. Complexity

While more complex facilities are related to more extensive venting and flaring, there is no relationship between facility complexity and whether or not the facility engages in the practice. According to Model 4, facilities with more drilled wellbores have no significant relationship with whether or not the facility vents or flares, but there is a significant positive relationship between facility wellbores and venting and flaring volumes. For every additional wellbore drilled at the facility, the expected amount of gas vented or flares increases by 0.2%, regardless of other facility, community and operator factors and this relationship is statistically significant. This suggests that because there are more wellbores where venting and flaring could occur, facilities with more wellbores vent and flare more gas than facilities with fewer wellbores.

However, at the operator-level, operators with more complex operations are more likely to engage in venting and flaring, but there is no relationship between operator complexity and venting and flaring volumes. According to Model 4, for every additional wellbore drilled by the operator, the expected odds a facility vents or flares increases by 0.009%, regardless of other facility, community and operator factors and this relationship is statistically significant. This suggests that, because operators with more wellbores drilled have more complex operations, they are more likely to vent or flare.

4.3.5. Economic Costs

Various economic costs come to play when operators decide whether or not to flare and to what extent. (1) Because there are few incentives for the company to build pipeline and invest in technology until after a well has been drilled and the productivity and potential of the well has been established, facilities with newly established wellbores are expected to vent and flare more. (2) Since the primary purpose of natural gas extraction facilities is to extract natural gas, no oil, it is expected that, in comparison to oil facilities, natural gas extraction facilities have a negative association with venting and flaring. (3) Because there are greater opportunities to pool group resources to build pipeline infrastructures in densely developed areas, dense oil and gas extraction development areas are expected to be negatively correlated with venting and flaring practices. (4) Since it is costlier to establish infrastructure and pipeline in areas that are far from already established pipeline, it is expected that the distance between the facility and established pipeline infrastructures is positively associated with venting and flaring practices.

As expected, facilities with newly drilled wells are more likely to vent or flare, and they vent and flare more gas than facilities where new drilling did not occur. According to Model 4, the estimated odds that a facility with newly drilled wells vents or flares is 10.5% greater than the corresponding odds for a facility that did not drill new wells, regardless of other facility, community, and operator factors and this relationship is statistically significant. Additionally, for facilities where new drilling occurred, the predicted venting and flaring volume would be 16% higher than for facilities where new drilling did not occur. This suggests that because it is more economical to flare the first few days upon completion rather than invest in green technologies, facilities with newly established wells are more likely to engage in venting and flaring.

Also as expected, facilities that are classified as gas extraction facilities are less likely to vent or flare and they vent and flare less than facilities classified as oil extraction facilities. According to Model 4, the estimated odds that a gas well vents or flares is 72% lower than the corresponding odds for an oil extraction facility and this relationship is statistically significant. Also, for gas extraction facilities, the predicted venting and flaring volume would be 18% lower than for oil extraction facilities, regardless of other facility, operator and community characteristics. This suggests that, because the primary purpose of gas wells is to collect extracted natural gas, gas extraction facilities are less likely to vent and flare than oil extraction facilities.

The density of oil and gas extraction facility development has no significant relationship between venting and flaring practices, but there is an inconsistent significant relationship between distance to nearest pipeline and venting and flaring practices. Operators claim venting and flaring practices are primarily due to lack of available pipeline and the cost and time it takes to build pipeline in undeveloped areas. However, facilities nearer to established natural gas pipeline are significantly more likely to vent or flare than those further away. According to Model 4, for each mile increase in distance between the facility location and nearest established natural gas pipeline, the estimated odds that the facility vented or flared decreases by 3%, regardless of other facility and operator factors, and this relationship is statistically significant. However, as expected, there is a significant positive relationship between the distance to the nearest pipeline and facility venting and flaring volumes. For each mile increase in distance between the facility location and nearest established natural gas pipeline, the predicted venting and flaring volume would increase by 10%, regardless of other facility, community, and operator factors, and this relationship is statistically significant. This suggests that because there are few incentives to build natural gas pipeline or invest in green completion equipment, an operator will choose to vent or flare, even though established pipeline is nearby. Also, because it is costlier to build natural gas pipeline when established pipeline is further away, an operator will vent and flare more gas at facilities where established pipeline is not nearby.

4.3.6. Organizational Structure

Natural gas is extracted using a drilling rig on top of one or more wells[4] within a lease[5] controlled by an operating company whose headquarters is typically at a separate physical

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[4] A well is a surface area drilled for the purpose of extracting petroleum crude oil and/or natural gas. The difference between a gas well and an oil well is the amount of raw gas that is produced in comparison to crude oil. Texas Natural Resources Code Sec 86.002 sets the ratio at 100,000 or more cubic feet of natural gas per every barrel of crude oil (Wilson 1977).

[5] A lease is a legal a deed which authorizes exploration and production of minerals for a specific tract of land, which is made up of one or more Census block groups. Texas gas leases consist of only one active well, whereas Texas oil leases consist of one or more active wells. According to Texas Railroad Commission records (See Appendix C for more details on how this information was obtained), in 2012, the median oil lease was 1 well. However, on average, leases consist of 4.36 wells with a standard deviation of 21.7. The number of active wells on oil leases ranged from 1 to 1765. In 2012, on average, Texas oil leases make up 1.1 Census block groups with a standard deviation of 0.8 and they span from 1 to 90 Census block groups.

location than the producing facility. Using business language, the natural gas production industry is organized as a set of branch plants[6] (i.e. extraction facilities, which are drilling rigs within a lease of land) controlled by central headquarters[7] (i.e. the operating company). Operating companies and extraction facilities can exist within a more complex organizational network (See *Figure 5*). When structured as a multilayer subsidiary organization, an operating company can be either a subsidiary or an ultimate parent company. A subsidiary, which can also be a parent company of another subsidiary, is a legally independent corporation with more than 50% of its stock owned by another company. The ultimate parent company is the top company within a corporate hierarchy, which owns one or more subsidiaries.

Prior research finds that because there is a legal buffer between subsidiary companies and ultimate parents, subsidiaries are more prone to pollution (Grant and Jones 2003; Prechel and Istvan 2016; Prechel and Touche 2014; Prechel and Zheng 2012). Findings further support this line of research; subsidiaries vent and flare significantly more gas than non-subsidiary organizations. According to Model 4, among venting and flaring facilities, the venting and flaring volumes of facilities that are operated by subsidiary organizations are about 3 times greater than facilities controlled by operators not organized using a multilayer subsidiary form. This suggests that because there is a liability firewall protecting ultimate parent companies from

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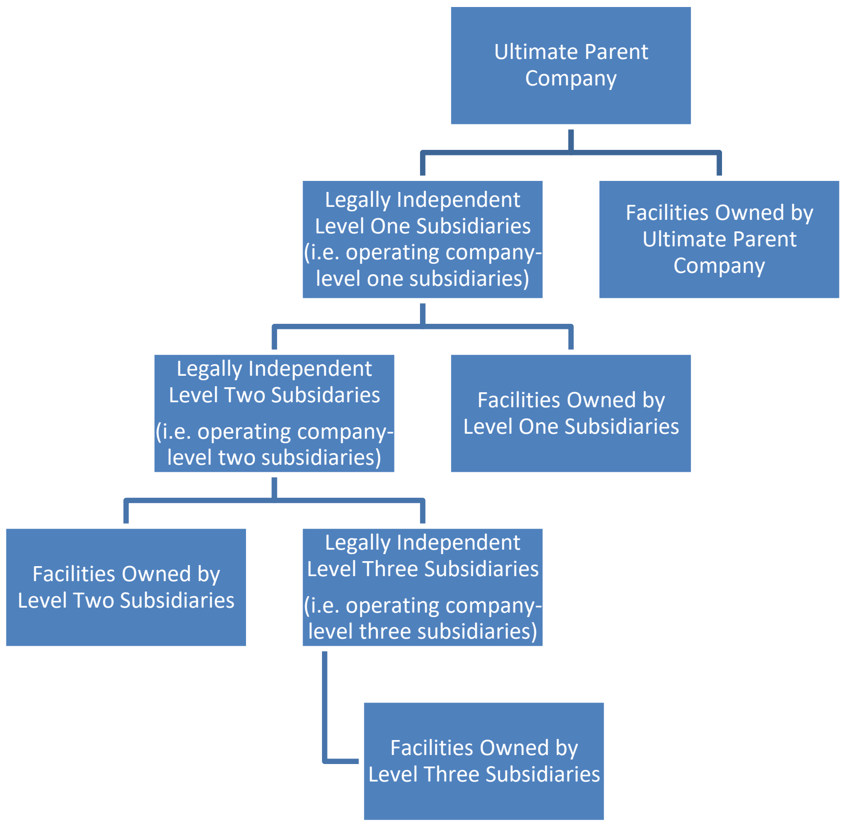
[6] According to Dun & Bradstreet (2015): “A branch is a secondary location of a business. It has no legal responsibility for its debts, even though bills may be paid from the branch location.”

[7] According to Dun & Bradstreet (2015): “A headquarters is a business location that has branches or divisions reporting to it, and is legally responsible for those branches or divisions.”

negative repercussions from extreme venting and flaring, subsidiaries vent and flare more than non-subsidiary organizations.

Figure 5. Proto-Typical Multilayer Subsidiary Form in the Oil and Gas Extraction Industry



4.4 How Social Organization Matters

In conclusion, organizational structures and the political and economic structures surrounding the organization effect venting and flaring. Findings show that the structure of the organization matters when explaining extreme venting and flaring. I find subsidiary companies vent and flare significantly more than other corporate types. These findings suggest because there is a liability firewall preventing companies from being directly responsible for extreme pollution, subsidiaries pollute more than non-subsidiary organizations. I also find that large oil production companies and facilities with more wellbores vent and flare more gas. These findings suggest that, because organizational inertia prevents large companies and more complex facilities from changing, larger, more complex organizations pollute more than smaller, less complex organizations. Findings also show that the economic structure in which oil and gas companies are embedded also effect industry venting and flaring practices. Results indicate facilities that vent and flare more gas are further from oil and gas pipelines, are oil leases, and have new drilling. This suggests that extreme venting and flaring is related to the immediate economic costs involved in building infrastructure and investing in green completion equipment and there are immediate economic gains from collecting petroleum and flaring the gas at oil sites. In addition, findings show that the political structure in which oil and gas companies are embedded affect industry venting and flaring practices. I find that venting and flaring practices have a positive correlation with state permitting. Extreme pollution is more likely when state regulation provides companies with legal opportunities to engage in extreme pollution practices.

5. CONCLUSION- A PLAN FOR CHANGE

> "The only way to get the whole industry working on the problem is to craft new regulations and enforce them" (Gunning 2014).

Legal, economic, and political frameworks support routine venting and flaring in Texas. By creating legal opportunities to unnecessarily vent and flare, state law and administrative code legitimates unnecessary venting and flaring. Since immediate financial incentives often outweigh the immediate economic costs of venting and flaring, prevailing economic structures encourage unnecessary venting and flaring. Furthermore, industry influence over TXRRC election and policy outcomes prevents the state from enacting strict anti-flaring regulation. Since prevailing legal, economic, and political structures support venting and flaring practices, in order to transform venting and flaring practices, political, legal, and economic structures must change. In this section, I discuss the need for change and lay out five recommendations. I conclude by summarizing the pathways to venting and flaring described in this thesis and how the recommended changes will eliminate current pathways.

5.1 The Need for Change

Although prevailing structures create incentives for individual operators to vent and flare, venting and flaring practices continue to produce immediate environmental harms for wider society and long-term economic harms for the individual operator. For economic, environmental, and social justice reasons, there is a need for current venting and flaring practices to change.

Venting and flaring is an economic waste for the state. Venting and flaring practices continue to expand, even as there is a bust. While prior to the shale oil boom in 2005, 7,743 million cubic feet of natural gas worth over $67 million was wasted by flaring or venting at extraction sites in Texas. In 2012, the amount grew over six fold to 48,192 million cubic feet worth nearly $228 million. The amount continues to expand. This waste of a finite natural resource results in immediate economic losses for the state and mineral rights owners.

Venting and flaring also contributes to global climate change. Flaring and venting releases a large amount of greenhouse gasses into the atmosphere including carbon dioxide and methane gas. In fact, flaring and venting is the largest source of methane emissions by the oil and gas industry (EPA 2017). This is particularly problematic because over the course of 100 years, methane contributes to climate change over 25 times as much as carbon dioxide (EPA 2015). Global climate change threatens our planet by changing global temperatures, leading to extreme weather patterns and rising sea levels. Since current venting and flaring practices by the oil and gas extraction industry is a major source contributing to climate change, it is important to change prevailing venting and flaring practices.

Finally, venting and flaring is problematic because it produces environmental injustices. In 2012, flaring conducted in the Eagle Ford Shale, which is just one of Texas' many oil and gas shale plays, led to over 15,000 tons of pollutants being released into the atmosphere, which is more than high-polluting Texas oil refineries (Tedesco and Hiller 2014). Flaring is the largest industrial source of smog, which exposes surrounding populations to potential negative health effects, such as asthma. Furthermore, as this research shows, the hazards of venting and flaring disproportionately rest on Hispanic populations. As such, it is a producer of environmental racism affecting a growing minority population.

In sum, regardless if you prioritize economic productivity or environmental and social justice, venting and flaring by the oil and gas industry is a problem. Additionally, venting and flaring is not a problem that is going away. Even as shale oil and gas development slow, venting and flaring practices continue to expand. As such, there is a growing need to change social structures to eliminate unnecessary routine venting and flaring practices.

5.2 Five Recommendations for Change

5.2.1 Strengthening Regulatory Frameworks

As described in Section 2, amendments to Statewide Rule 32 created legal opportunities for companies to waste gas that could otherwise be sold for a profit. In order to ensure companies do not continue wasteful practices, TXRRC must eliminate legal loopholes. Therefore, I recommend the advice of legal scholar and professor Brett Wells, JD (2014:355), that "statewide Rule 32 be amended to allow the flaring of natural gas only after the operator establishes that a no-flare policy would itself result in physical waste or would represent a potential loss of one's opportunity to obtain a fair share of the oil and gas in place." This would ensure RRC policy prioritizes its original purpose to minimize waste while still ensuring companies are able to fairly participate in the market.

5.2.2 Campaign Finance Reform

Prior to its establishment as an oil and gas regulatory agency, RRC was changed to be run by three elected officials rather than appointed ones. With big financial interests, RRC elections have become dominated by the oil and gas industry. In order to keep industry money from dominating local politics, Texas state legislature must enact campaign finance reform laws. First of all, state laws should limit the time and amount of financial contributions that can be received by those running for office. By creating a lower threshold for the length and financial resources of a campaign, unfair industry influence on RRC election actions can be minimized. Also, to ensure RRC commissioners do not use their power to ensure industry support for a re-election campaign, RRC commissioners should only be allowed to serve one term in office. By shifting power away from industry selected RRC candidates and toward RRC state managers (while keeping industry power over state managers in check by the continued enforcement of Texas revolving door provisions), industry dominance of RRC outcomes can be minimized.

5.2.3 Strengthening Fiscal Frameworks

As described in section 2, since companies face few, if any, economic repercussions for venting and flaring, there are few financial incentives for companies to eliminate flaring. Since corporate boards are often judged by quarterly profit reports, financial incentives and penalties drive corporate behavior. This is especially true regarding venting and flaring. As shown in the previous section, extreme pollution is associated with economic costs such as the development of pipeline structure, new drilling, and the primary commodity of the facility. Since natural gas is the primary commodity of gas extraction facilities, in comparison to oil extraction facilities, gas extraction facilities vent and flare at a much lower rate. Also, since there are immediate economic costs with purchasing green completion equipment, facilities with new drilling vent and flare more gas than those without new drilling. Furthermore, because there are more costs associated with building pipeline infrastructure in remote locations, there is a significant positive correlation between the distance to the nearest pipeline and extreme venting and flaring.

State created fiscal frameworks can be used to eliminate routine venting and flaring (World Bank 2009). Fiscal frameworks must enhance the financial penalties for venting and flaring and enhance the incentives to utilize gas that is otherwise being vented or flared using a two-pronged penalty and incentive approach. A penalty approach should be taken by the Texas legislature to provide the RRC with the resources and mission to routinely identify and heavily fine venting and flaring facilities. The financial incentives approach should be taken by the RRC by reducing taxes on facilities that invest in the development, purchase, or rental of gas utilization equipment. This two-pronged approach must shift conditions such that the financial incentives to utilize extracted natural gas will outweigh the financial costs. Since money matters to corporations, shifting the financial conditions involved in decisions to vent and flare will change venting and flaring outcomes.

5.2.4 Using Litigation to Force Compliance

There are several avenues for mineral rights owners, surface rights owners, and adjacent landowners to use private litigation to force companies to eliminate wasteful venting and flaring practices (Wells 2014). First of all, to sue venting and flaring operators, mineral rights owners can use legal president that the mineral rights owner is entitled to receive maximum gross royalties (Natural Gas Pipeline Co. of America v. Pool), and the fact that flaring reduces gross royalties. Second, surface rights owners can sue venting and flaring operators by using tort law to claim that venting and flaring is a nuisance that affects air quality. By enacting the legal advice laid out in the Texas Journal of Oil Gas and Energy Law (Wells 2014), mineral rights owners, surface rights owners, and adjacent landowners can use private litigation to legally force companies to eliminate venting and flaring. Based on historical evidence described in Section 2, litigation is a critical component in forcing companies to eliminate unnecessary venting and flaring practices.

5.2.5 Increasing Public Access to Information

Prior to this research, point-level maps of venting and flaring volumes were not publicly available. To create these maps, in addition to using GIS resources made available through a National Science Foundation Grant and affiliation with Texas A&M University, RRC required several thousand dollars of payments. While Texas law allows state agencies to have the <u>option</u> to waive fee requirements if the information will primarily benefit the public, even though it was not disputed that by producing mobile-friendly GIS maps of the data, the research will primarily benefit the public, Public Information Act fee waivers were denied. In addition to the large economic cost to access comprehensive information about lease venting and flaring estimates, a large amount of technical skill and time was required to examine the places most affected by venting and flaring. As described in the Appendix, to find the places where venting and flaring occurs required connecting multiple datasets and making multiple requests for information since information provided was incomplete. In order to make information more accessible to the public, the Texas Railroad Commission should be required waive all Public Information Act fee requests for academic researchers and to make editable online maps of monthly and yearly venting and flaring estimates.

5.3 Conclusion

This thesis explored the social structures that support extreme pollution from venting and flaring. These structures are described as coercive, quiescent, expropriative and inertial. Coercive structures involve those that provide minimal local resistance to extreme pollution through hard power. I find the coercive power of the state has a major effect on venting and flaring practices. Quiescent structures involve those that provide minimal local resistance to extreme pollution through soft power. The quiescent power of operators, like the positive economic effects on surrounding communities and the influence of large oil companies such as Exxon in informing Texas oil and gas industry venting and flaring regulations, affects the venting and flaring practices of organizations. Expropriative structures, which involve the weighing of economic costs and incentives, are also major factors. Finally, I find inertial structures, like the size and complexity of organizations, are related to extreme pollution. However, due to a lack of comprehensive public data, inertial structures such as ultimate parent company size and age were not examined. Future research should examine these configurating using restricted business data available in a Federal Statistical Research Data Center.

In order to change venting and flaring practices, we must change these coercive, quiescent, expropriative, and inertial structures that support them. This can be done by strengthening regulatory frameworks, enacting campaign finance reform, strengthening fiscal frameworks, using private litigation to force compliance, and increasing public access to information. By closing loop holes that allow unnecessary venting and flaring, by providing accessible information to affected communities, and by encouraging the pursuit of private litigation in cases where companies unnecessarily vent and flare, coercive structures can be strengthened to eliminate unnecessary venting and flaring. Quiescent structures, like the influential soft power of money in campaign finance, can also be enhanced to decrease the power of hyper-polluters. Finally, the expropriative structures contributing to flaring can be improved by changing fiscal frameworks such that the costs of venting and flaring outweigh the financial incentives to fail to invest in the technology, equipment, and infrastructure necessary to eliminate routine venting and flaring. While venting and flaring is a growing concern, venting and flaring practices are not normal or inherent; they are the result of socially constructed political, legal, and economic arrangements. By changing these man-made social structures, venting and flaring can be a problem of the past.

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APPENDIX A

As the environmental justice movement grew in impact, so did debate over how to best assess and quantify environmental inequality. Environmental inequality research traditionally focuses on the communities disproportionately exposed to the environmental harms of capitalist production (Bullard 1990). However, a new line of research focuses on the facilities disproportionately responsible for toxic emissions and the communities surrounding facility locations (Grant, Trautner, Downey, and Thiebaud 2010). In sum, there is a methodological debate regarding quantitative environmental justice analysis. Much of the debate centers on determining emission sources, measuring proximity to environmental risks and defining the unit of analysis (Liu 2001).

In this appendix, I argue that “bringing the polluters back in” to environmental inequality analysis (Grant et al. 2010) is critical to understand how environmental inequality is produced. There are both broad and narrow purposes for this appendix. The broad goal is to discuss methodological debates among quantitative environmental justice scholars. The narrower purpose is to make an argument for the methodological approach to environmental inequality used throughout this monograph.

A.1 Determining Emission Point Sources

Environmental inequality research traditionally involves point source pollution. Point source pollution is pollution that can be attributed to a primary point source, such as an industrial production facility. Common point source pollution data comes from the Environmental

Protection Agency Toxic Release Inventory (EPA TRI) and the Environmental Protection Agency Greenhouse Gas Reporting Program (EPA GHGRP). However, there are limitations associated with using these data sources, particularly as it pertains to the oil and gas extraction industry.

A.1.1 Environmental Protection Agency Toxic Release Inventory (EPA TRI)

The EPA TRI was created by under the Emergency Planning and Community Right to Know Act signed into law on October 17, 1986 by President Reagan. To assist preparedness for chemical spills, the EPA TRI provides communities with information on chemicals used at some industrial production facilities. Facilities must meet three criteria to be required to report to the EPA TRI: (1) it must be within a specific industrial sector, (2) it must employ 10 or more full-time employees, and (3) it must handle 25,000 pounds of chemicals or more within the year. The oil and gas extraction industry is exempt from reporting.

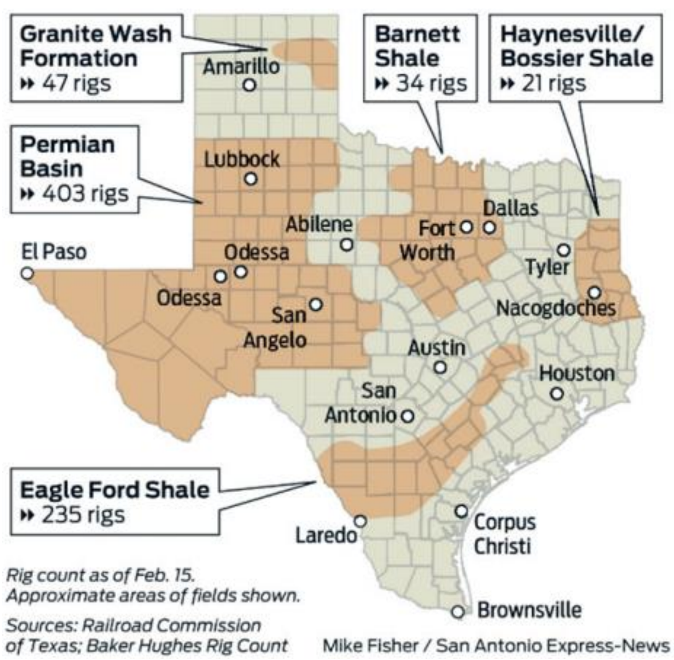
A.1.2 Environmental Protection Agency Greenhouse Gas Reporting Program (EPA GHGRP)

Responding to the passage of the FY2008 Consolidated Appropriations Act, the EPA established the GHGRP. Starting in 2010, the EPA began to collect greenhouse gas emissions data from all facilities and automotive fleets that emit 25,000 metric tons of carbon dioxide equivalent or more per year. While the oil and gas extraction industry is required to report, information is not for specific facility points. Instead, information is for oil and gas extraction facility operations across entire shale plays, which is a very large geographic area. This provides little information about the specific place where pollution occurs.

A.1.3 Problems with Environmental Protection Agency Data Sources

Information submitted to the EPA is limited, as specific industries are exempt from reporting to the EPA, the EPA fails to collect information on small producers, and information collected by the EPA on the oil and gas extraction industry is for large geographic areas, not specific points. The example below demonstrates limitations.

Figure 6. Example Operator Oil and Gas Extraction Facility Span Across Texas Counties



Source: Hiller, 2013 [Reprinted]. Reprinted with permission from "A 21st-Century oil boom in the Lone Star State; Texas has nearly half of all rigs in the United States" by Jennifer Hiller, 2013. *San Antonio Express News*, Copyright 2013 by Zuma Press.

The figure above shows Baker Hughes (a large oil and gas extraction company) oil rig counts for the various shale plays in Texas. Rigs are the mechanical devices used to extract oil and gas at a lease (i.e., it is a machine used at an oil and gas extraction facility). Emissions from these facilities would not be submitted to the EPA TRI because the oil and gas extraction industry is exempt. Baker Hughes would be required to submit a record to the EPA GHGRP for each of the separate shale formations if greenhouse gas emissions from rigs within the shale emit 25,000 tons or more of greenhouse gases. For example, if the 21 rigs located in the Haynesville/Bossier Shale were estimated to emit 23,000 tons of greenhouse gases, it would not be required to report. On the other hand, say the 235 rigs in the Eagle Ford Shale emitted 25,000 tons or more of greenhouse gasses, Baker Hughes would be required to submit a single report for all 235 rigs. Information is not broken down to the 235 facilities spread across the shale play. The specific locations of the facilities where emissions are occurring are not even collected. As such, using the EPA GHGRP, we cannot tell which communities are living near the oil and gas extraction facilities where pollution occurs.

A.2 Measuring Community Environmental Risks

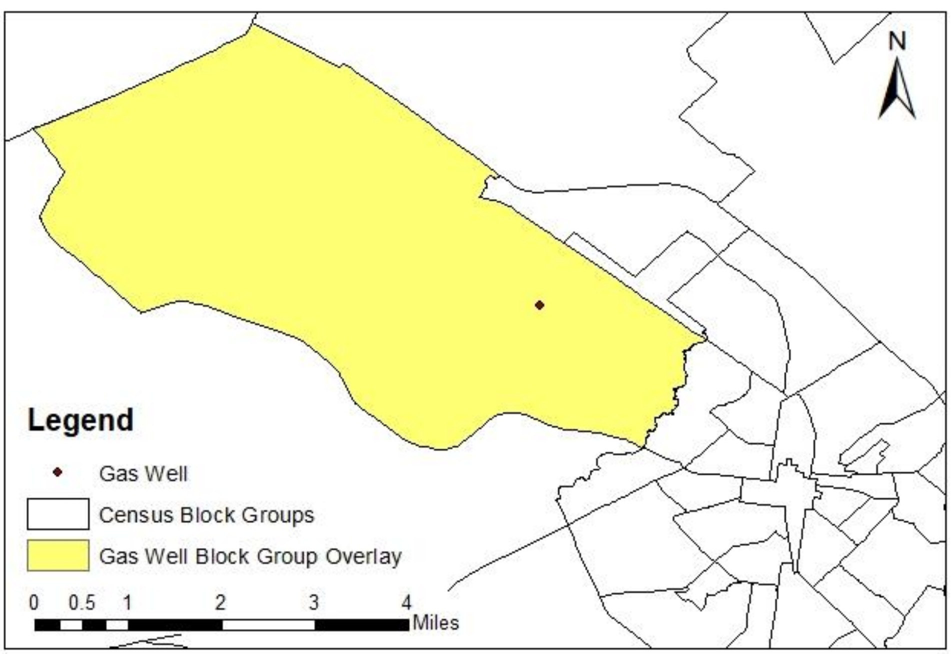
Two key issues among sociologists quantifying environmental risks are: (1) how to measure proximity to risk, and (2) how to best estimate emission magnitude.

A.2.1.1 Unit Hazard Coincident Approaches

There are two key approaches to measuring proximity to environmental risks: the traditional unit hazard coincident approach, and the more modern, distance-based approach.

Traditional environmental inequality analysis relied upon a unit hazard coincident approach. Classical studies examined whether or not a locally unwanted land use (LULU) was located within community boundaries (Bullard 1990; Mohai and Bryand 1992). In essence, this approach quantifies the characteristics of the immediate community in which the toxic facility is located, in comparison to those of the population not in the same immediate area. The spatial relationship between the facility and the community is determined by overlaying community boundaries and facility points to determine the community in which the facility is located.

Figure 7. Example Unit Hazard Coincident Approach

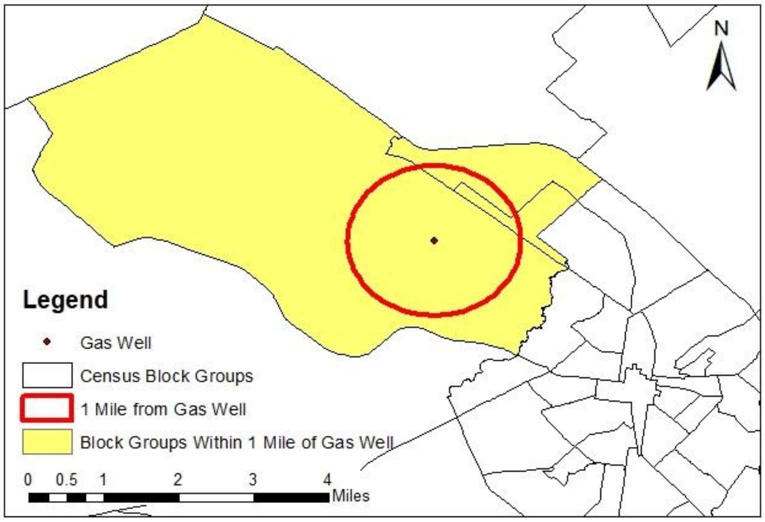


However, the unit hazard coincident approach is problematic, especially for facilities located near boundary lines. The community effected by toxic facilities often goes beyond the man-made boundary in which the facility is located.

A.2.1.2 Distance-Based Approaches

More modern approaches to quantifying environmental inequality use geographic information technologies to determine the communities surrounding toxic facilities. The example below demonstrates a simple boundary intersection distance-based approach. This approach quantifies the characteristics of communities surrounding facilities by determining the communities whose boundaries are within a specific distance from the facility and aggregating community data.

Figure 8. Example Distance Based Approach



When comparing unit hazard coincidence and distance-based approaches, Mohai and Saha (2007) find distance-based approaches are robust and provide more precise estimates of communities exposed.

A.2.2 Measuring Emissions

Sociologists use various approaches to estimate the magnitude of industrial facility toxic emissions. While emission models are most commonly used, another approach is to use direct metering devices.

A.2.1.1 Emission Models

EPA GHGRP greenhouse gas emissions are estimated using a variety of different models. Some estimate emissions by examining fuel-specific data. Others simply multiply a default emission and heat factor by the amount of fuel used to estimate carbon dioxide, methane, and nitrous oxide emissions.

A.2.1.2 Metering Devices

Some facilities employ continuous monitoring systems located on flare stacks, which monitor toxic emission concentration and flow rate. While this provides the most precise emission estimates, it is costlier to implement.

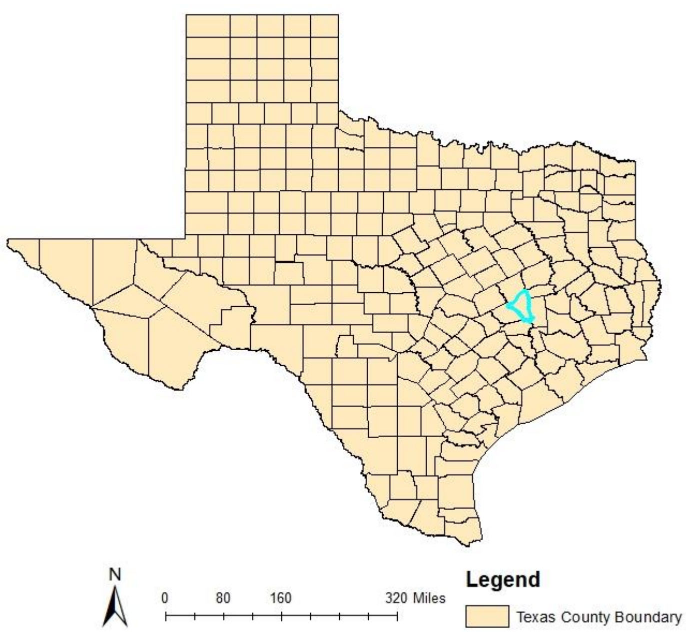
A.3 Defining the Unit of Analysis in Community-Level Research

Much debate revolves around the ideal unit of analysis when conducting community-level environmental inequality research. Commonly used units of analysis (from largest geographic scale to smallest geographic scale) include county boundaries, zip code boundaries, Census tract boundaries, and Census block group boundaries.

A.3.1 County Boundaries

Counties are very large geographic areas commonly used in environmental inequality analysis. Below is a map of all Texas counties, with Brazos County highlighted. Brazos County is at the upper edge of the Eagle Ford Shale.

Figure 9. Texas County Boundaries in 2012



In 2012, there were 254 counties in Texas. The mean county size was 1062 square miles with a standard deviation of 658 square miles.

A.3.2 Zip Code and Census Tract Boundaries

Since counties are so large, zip codes and Census tracts are more commonly used units of analysis in quantitative environmental inequality research. Zip codes and Census tracts are smaller geographic areas in comparison to counties, but still spread across a large geographic area. While Census tracts are contained within counties, zip codes can spread across counties. Below is a map of all zip codes and Census tracts within in Brazos County, with a single Census tract in West Downtown Bryan highlighted.

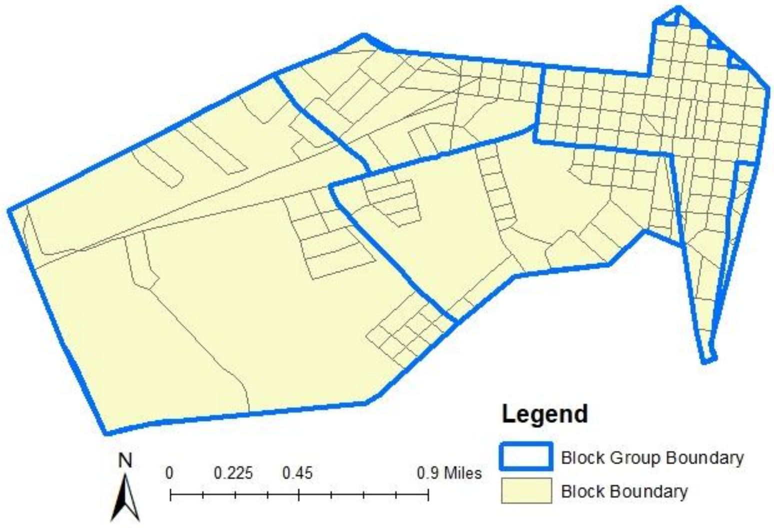
Figure 10. Example Texas Zip Code and Census Tract Boundaries in 2012

In 2012, there were 2024 zip code areas in Texas. The mean zip code area was 115 square miles with a standard deviation of 198 square miles. In 2012, there were 5313 Census tracts in Texas. The mean tract area was 51 square miles with a standard deviation of 210 square miles.

A.3.3 Census Block Group and Block Boundaries

Census block groups are much smaller than Census tracts and zip codes, and Census blocks are even smaller than block groups. Below is a map of the Census tract in West Downtown Bryan (which was highlighted in the previous map) and the Census blocks and block groups within the tract.

Figure 11. Example Texas Block Group and Block Boundaries in 2012



As you can see, Census block groups and blocks are much smaller than tracts. The American Community Survey (ACS) provides detailed five-year community demographic and economic estimates at the block group level to the public. Block-level ACS community estimates are restricted and unreliable, as the ACS was sampled at a higher level of geography. In 2012, there were 15,799 Census block groups in Texas. The mean block group area was 17 square miles, with a standard deviation of 103 square miles. In 2012, there were 917,499 Census blocks in Texas. The mean block group area was .3 square miles with a standard deviation of 1.74 square miles.

A.4 Conceptual Limitations of Community-Level Research

In sum, environmental inequality research primarily focuses on the community as the unit of analysis. Electronically metered, distance based, block group-level approaches provide the most precise estimates of communities most affected by facility toxic emissions. However, with the community as the primary focus of environmental inequality, little attention is paid to how variation between facilities relates to environmental inequality. Instead, much of environmental inequality research conceptualizes all toxic facilities as the same. However, rural sociology research on disproportionality demonstrates a significant variation among facility emission *rates* within an industry (Freudenberg 2006). It is critical to use the facility, which is the producer of environmental inequality, as the unit of analysis so that we can better understand why some facilities pollute at a higher rate than others.

A.5 Bringing the Facility into Environmental Inequality Research

A.5.1 Prior Research

Much of environmental inequality research focuses on the community while overlooking toxic facilities themselves. However, because they are the producers of environmental inequality, Grant, Trautner, Downey and Thiebaud (2010) shift the focus to the industrial facility. Using novel fuzzy set qualitative comparative analysis and the Environmental Protection Agency's Risk-Screening Environmental Indicators (RSEI) of 2,053 chemical industry plants in 2002, they find that community and facility characteristics combine to produce disproportionate pollution emissions. Facilities in Census tracts that are more black, more Hispanic, or have a greater percentage of the population employed in manufacturing, and facilities that have more employees or are branch plants are more likely to have highly risky emissions (Grant et.al 2010).

While Grant et. al (2010)'s research involving the industrial facility in environmental inequality analysis is a critical advancement, it is methodologically limited in four key ways. First, the research relies upon the Environmental Protection Agency's RSEI model. The RSEI model evaluates the environmental risk of a facility using information about chemicals reported to the EPA TRI, together with factors about the chemical's toxicity and potential for human exposure. As described earlier, the EPA TRI is limited, as the only companies required to report are those that emit 25,000 tons of chemicals annually and have 10 or more full time employees. Since most organizations are small (Granovetter 1984), failing to include small organizations in their analysis limits the scope of their findings. Second, the research relies on a less precise method of measuring community proximity to risk. While Grant et. al (2010) use a unit hazard coincident approach to determining the characteristics of communities surrounding facilities, as described earlier, a distance-based approach is much more precise. Third, the research relies on community information at the Census tract-level, which is a much larger geographic unit of analysis than the Census block group. Forth, Grant uses fuzzy set qualitative comparative analysis methods to determine which combinations of facility and organizational characteristics best explain facility emissions. While this is an innovative method to conduct exploratory research, it is not theory driven, it is data driven. As such, it is more difficult to differentiate genuine relationships from spurious ones.

A.5.2 My Approach

I overcome previous limitations by taking a different approach. The approach taken in this project is inspired by Grant et. al (2010)'s work but makes up for methodological limitations to studying the oil and gas extraction industry. While Grant et. al (2010) relies upon the EPA TRI and RSEI model to determine emission point sources and emission volumes, my research uses the Texas Railroad Commission well surface location coordinates for all producing oil and gas extraction facilities and electronically metered oil and gas production and disposition volumes. Additionally, I employ a distance-based, block group method to determine the characteristics of communities most effected by oil and gas extraction facility venting and flaring volumes. Finally, I use a theory driven, quantitative regression model at the oil and gas extraction facility-level to determine how the characteristics of communities surrounding facilities are related to disproportionate emissions. While my approach is briefly described below, a detailed description of specific terms and models is in the subsequent appendix.

A.5.2.1 Determining Emission Point Sources- Texas Railroad Commission Well Surface Location Coordinates

While federal agencies do not collect the longitude and latitude coordinates on all oil and gas extraction wells, state agencies make this information available to the public, though sometimes at a cost. Wellbore surface location coordinates were obtained for all oil and gas wells from the Texas Railroad Commission. Prior to drilling in Texas, all companies are required to report wellbore surface locations to the Texas Railroad Commission. These wellbore surface locations were projected onto a map using a North American Datum 1983 State Plane Texas Central FIPS 4203 Feet. While wellbore surface locations are available to the public though a GIS viewer, this information is not available to be downloaded and used to conduct comprehensive geographic and statistical analysis. As such, these coordinates were obtained through several Public Information Act requests to the Texas Railroad Commission. The Texas Railroad Commission required several thousands of dollars in processing fee payments (requests to waive the fee were denied), which were paid by the Texas A&M Sociology Department Graduate Research Award Committee.

A.5.2.2 Measuring Proximity- A Distance-Based Approach

I employ a boundary intersection distance-based approach to quantify the characteristics of individuals and households living in Census block groups within one mile of the wellbore surface location. First, I projected wellbore surface locations and 2012 Census TIGER/Line Shapefiles onto a map using a North American Datum 1983 State Plane Texas Central FIPS

4203 Feet. Then I drew a one-mile buffer around each wellbore surface location. Next, I overlaid the one-mile buffer with Census block group polygons. Finally, I aggregated the block group data by the unique oil and gas extraction facility identifier to quantify the characteristics of communities living in block groups within one mile of the facility. I chose a one-mile buffer over other distances, as Moahi and Saha (2007) find it provides a more precise estimate and better fits the environmental inequality hypotheses.

A.5.2.3 Measuring Emissions- Metered Volumes

I obtained venting and flaring gas volumes in thousand cubic feet (at base pressure of 14.65 pounds per square inch and base temperature of 60 degrees Fahrenheit) from the Texas Railroad Commission. Statewide Rules 27, 54 and 58(b) require all operators submit monthly production reports for each oil and gas extraction facility. Venting and flaring volumes obtained from thermal mass flow meters are required to be submitted on these monthly reports. For each oil and gas extraction facility, I aggregated the recorded volumes for each month of 2012. Metered volumes are better than operator estimates, as it minimizes human error.

A.5.2.4 Defining the Unit of Analysis- Oil and Gas Extraction Facility

While much research relies on the community as the unit of analysis, I rely upon the oil and gas extraction facility. The oil and gas extraction facility involves one or more wellbore surface locations located on the same lease of land. My research involves all producing oil and gas extraction facilities in 2012. I describe these facilities in more detail in *Appendix B* and *C*.

APPENDIX B

In this appendix, I review the analytical strategies behind the analysis of the communities most exposed to Texas oil and gas venting and flaring volumes in 2012. In essence, this appendix provides more details about the methods and findings underlying the research presented in section 3.

B.1 Research Methods

B.1.1 Units of Analysis, Population, and Sample

This study involves all producing Texas oil and gas extraction facilities within one mile of Texas Census block groups and Texas Census block groups in 2012. Two separate analysis are conducted at different units. One study focuses on the oil and gas extraction facility. The other study focuses on the Census block group. Analysis primarily focuses on all producing Texas oil and gas extraction facilities that submitted their monthly production and disposition report in 2012 that are within a mile of a Census block group with at least one American Community Survey five-year summary file block group estimate publicly released. This means that oil and gas extraction facilities not near residential populations or those within one mile of Census block groups with so few residents that estimates cannot be publicly released due to confidentiality reasons are not included in my analysis. In 2012, there were 162,144 producing oil and gas extraction facilities and 126,862 were located within one mile of a block group with a corresponding American Community Survey five-year summary file publicly available population estimate. This means that 35,282 producing oil and gas extraction facilities were not included in the analysis because they were not located within one mile of a block group estimate, often because they were located near areas where there are no residents, such as airports, military training grounds, and off-shore. All Census block groups located in Texas with demographic characteristics publicly released in 2012 are also analyzed. In 2012, there were 15,810 census block groups in Texas and 15,771 had publicly released demographic estimates. This means that 39 block groups were not included in the analysis because they had so few residents that estimates were not publicly released due to confidentiality reasons.

B.1.2 Data Sources

This study relies on four different sources: (1) Texas Railroad Commission database, (2) American Community Survey five-year summary file population estimates, (3) the National Center for Charitable Statistics database, and (4) Texas Statewide Imagery Political Boundaries shapefiles.

B.1.2.1 Texas Railroad Commission Database

Various datasets from the Texas Railroad Commission were used to map Texas oil and gas venting and flaring volumes. Datasets include the Production Data Query Dump, a programmed request GIS data extract, the Full Wellbore Query Data, the Drilling Permit Master and Trailer Plus Longitudes and Latitudes file, and Digital Map Information. These files were all required to obtain a 100% match between production files and extraction facility geographic coordinates. Fees to process Public Information Act requests for this information were paid by the Texas A&M University Sociology Department Graduate Research Award Committee.

B.1.2.1 Production Data Query Dump

This dataset is a complete dump of the Texas Railroad Commission production database. The production database contains all oil and gas production and disposition records submitted by all operating oil leases and gas wells each month since 1992. Organizations are required to report the actual electronically metered volumes of gas production and disposition and there are financial consequences for failing to correctly report. Accounting for lags in reporting, aggregated Texas Railroad Commission production estimates match Energy Information Administration state-level reports (EIA 2015). However, unlike Energy Information Administration state-level reports, the Texas Railroad Commission production dataset provides information necessary to link production and disposition data to the specific point location where production and disposition occurs. This dataset was received on May 4, 2016 a series of .dsv files. Two .dsv files from this dataset were used: OG_LEASE_CYCLE_DATA_TABLE.dsv and OG_LEASE_CYCLE_DISP_DATA_TABLE.dsv. The codebook for this dataset is available at http://www.rrc.state.tx.us/media/1286/pdqdump.pdf.

B.1.2.1.2 Full Wellbore Query Data

The Wellbore Query Data is necessary to connect the Production Data Query Dump with other datasets that rely upon American Petroleum Institute (API) numbers rather than Texas

Railroad Commission assigned unique identifiers. This dataset provides the API numbers associated with particular Texas Railroad Commission lease and district numbers. This data was received on May 10, 2016 as a single test file: dbf600.txt. The codebook for this dataset is available at http://www.rrc.state.tx.us/media/24474/wba091_wellbore_october2014.pdf.

B.1.2.1.3 Drilling Permit Master and Trailer Plus Longitudes and Latitudes Dataset

The Drilling Permit Master and Trailer Plus Longitudes and Latitude dataset contains information on every permit application submitted to drill or conduct production and disposition activities at an oil or gas well since 1976. All organizations drilling any type of oil or gas well must obtain and maintain an oil and gas permit. There are financial penalties associated with failure to maintain an oil and gas permit. The ASCII file is updated daily and contains drilling permit information and well completion and restriction information including GIS coordinates of all Texas oil and gas well surface locations referenced to North American Datum 1927 (NAD27). This file was received on May 6, 2016 as a single .dat file: daf802_II.dat.gz. The codebook for this dataset is available at http://www.rrc.state.tx.us/media/20754/drilling-permit-master-and-trailer-plus-latitudes-and-longitudes-user-manual.pdf.

B.1.2.1.4 Programmed Request Data Extract

Geographic coordinates in North American Datum 83 (NAD83) were also requested through a programmed request. This dataset was received on April 11, 2016 as a single text file: Well_GIS-4.11.txt.

B.1.2.1.5 Digital Map Information

Since there was still an incomplete match between production data and facility geographic coordinates, I finally obtained a complete match using well surface location coordinates from the Texas Railroad Commission Digital Map. This dataset, received on January 11, 2017, came as a series of shape files (Shp001.zip, Shp003.zip, …, Shp507.zip) referenced to NAD83.The codebook for this dataset is available at http://www.rrc.state.tx.us/media/36706/digital-map-information-pdf.pdf.

B.1.2.1.6 American Community Survey Five-Year Summary File Population Estimates, Geodatabase Format

The 2010-2014 American Community Survey five-year population estimates geodatabase was used to obtain residential community information. The five-year population sample of 2010-2014 is used because five-year estimates are recommended when examining areas with populations lower than 20,000 (Census Bureau 2015). American Community Survey data provides community demographic information at the block group-level. The geodatabase format of the American Community Survey brings together geography from the Census Topologically Integrated Geographic Encoding and Referencing (TIGER)/Line Shapefiles and the American Community Survey five-year estimates in a Geographic Information System (GIS). The American Community Survey five-year estimates geodatabase is referenced to NAD83.

B.1.2.1.7 National Center for Charitable Statistics Database

The National Center for Charitable Statistics database includes information about registered charitable organizations throughout the United States. Information about the number of registered nonprofit organizations found before 2012 in each Texas county was obtained using the database accessible at http://nccsweb.urban.org/PubApps/geoCounties.php?q=TX.

B.1.2.1.8 Texas Statewide Imagery Political Boundaries Shapefiles

In order to determine the county in which the oil and gas extraction facility is located, I used the Texas Statewide Imagery Political Boundaries geodatabase available at the Texas Natural Resources Information System data download page: https://tnris.org/data-download/#!/statewide. The geodatabase (political-bnd_tx.zip) was downloaded on January 19, 2017. The county boundary shapefile (StratMap_County_poly.shp) is referenced to NAD83.

B.1.3 Detailed Measures

Household income and home value categories are described in the tables below. These categories were chosen because they are the categories available using public Census files.

Table 5. Household Income Categories

Category	Household Income Range
1	< $10,000
2	$10,000 – $14,999
3	$15,000 - $19,999
4	$20,000 – $24,999
5	$25,000 - $29,999
6	$30,000 – $34,999
7	$35,000 - $39,999
8	$40,000 – $44,999
9	$45,000 - $49,999
10	$50,000 – $54,999
11	$55,000 – $59,999
12	$60,000 – $74,999
13	$75,000 – $99,999
14	$100,000 – $124,999
15	$125,000 – $149,999
16	$150,000 – $199,999
17	> $200,000

Table 6. Home Value Categories

Category	Home Value Range
1	< $10,000
2	$10,000 – $14,999
3	$15,000 - $19,999
4	$20,000 – $24,999
5	$25,000 - $29,999
6	$30,000 – $34,999
7	$35,000 - $39,999
8	$40,000 – $44,999
9	$45,000 - $49,999
10	$50,000 – $54,999
11	$55,000 – $59,999
12	$60,000 – $69,999
13	$70,000 – $79,999
14	$80,000 – $89,999
15	$90,000 – $99,999
16	$100,000 – $124,999
17	$125,000 – $149,999
18	$150,000 – $174,999
19	$175,000 – $199,999
20	$200,000 – $249,999
21	$250,000 – $299,999
22	$300,000 – $399,999
23	$400,000 – 4399,999
24	$500,000 – $749,999
25	$750,000 – $999,999
26	> $1,000,000

B.1.4 Connecting Texas Railroad Commission Datasets

Data management started by connecting monthly venting and flaring volume records with production records. The lease-level production table was first connected to the lease-level monthly disposition table using a unique identifier made up of the oil/gas code, district number, lease number, month, and year. Once these files were connected, I kept only those for 2012, created an identifier made up of the oil/gas code, district number, lease number, and operator number, and found the volume of gas produced and dispose for each operator's lease.

Next, I connected the production and disposition query dump data with the full wellbore query data using an identifier made up of the oil/gas code, district number and lease number. To do this, I had to first parse out the information for each table included within the given ascii file and re-connect the tables to obtain single rows of all wellbore information available within the file. Then, I removed all wellbores that were not active in 2012. Finally, I connected leases to their respective wellbores.

After that, I connected the production and disposition data with the programmed request data using the API number. I also attempted to match production and disposition data with wellbore surface locations in the permit master file (which has wellbore surface locations in NAD27 format) using the API number. In order to do this, I first parsed out the information within the permit master file into various tables and re-connected the tables to obtain single rows of all wellbore information within the permit file. Finally, a complete match between production data and well coordinates was obtained by matching production data with the digital map information (referenced to NAD83) using the API number.

B.1.5 Creating the Geographic Information System

Other datasets were matched within a Geographic Information System, using the following steps. First, all geographic data (wellbore coordinates, American Community Survey block group shapefile, and Texas county boundaries shapefile) was added to the map and projected to North American Dam NAD83 State Plan Texas Central FIPS 4203 Coordinate System. Oil wellbore coordinate points were then grouped for each operator's lease, representing numerous wellbore surface locations on the same lease. Oil lease and gas wells were overlaid with the county boundary file, and then matched to the National Center for Charitable Statistics county nonprofit organization information using the county name. Then, a one-mile buffer was drawn around oil lease multi-points and gas well points and then it was overlaid with the block group boundary file. Finally, American Community Survey estimate tables were connected to the block group-lease buffer overlay file using the block group number (I.e., geoid). Once the datasets were connected within the Geographic Information System, information was reconnected to production data and collapsed to create single facility and block group files.

B.1.6 Data Analysis

This research uses a zero-inflated negative binomial model in order to determine correlations between the amount of gas vented or flared and community characteristics. Negative binomial regression accounts for separate processes related to the of prediction the dependent variable at zero and elsewise. Zero-inflated negative binomial regression modeling is a three-step process. First, it predicts whether or not the unit is zero. Second, it predicts variation in the dependent variable for units that are not zero using a Poisson-gamma mixture distribution. Finally, it computes the observed probabilities as a mixture of the probabilities of the two different latent groups. Tobit, Ordinary Lease Squares, Poisson, zero-inflated Poisson, and negative binomial regression models were considered but not chosen due to problems with the violation of normality and heteroskedasticity assumptions. A zero-inflated negative binomial regression was chosen over Poisson, zero-inflated Poisson, and negative binomial regression models because the zero-inflated negative binomial regression model provided a better fit when comparing Akaike Information Criterion estimators.

The zero-inflated negative binomial regression model first predicts whether a unit (i.e., block group or facility) is associated with zero gas vented or flared. Units with zero venting and flaring volumes are considered in “Group A”. The probability of being in “Group A” is estimated using the following equation:

$$\Pr(A_i = 1 \mid z_i) = \psi_i = F(z_i \Upsilon) = \frac{exp(\Upsilon_0 + \sum_{k=1}^{n} z_k \Upsilon_k)}{1 + exp(\Upsilon_0 + \sum_{k=1}^{n} z_k \Upsilon_k)}$$

Let $A_i = 1$ if the unit is in Group A, else $A_i = 0$, where ψ_i is the probability of being in Group A for unit i, z_k is the inflation variable, Υ_0 is the intercept and Υ_k represents regression coefficients.

Then, among units that reported at least one mcf of gas vented or flared, the volume of gas vented or flared was estimated using the following equation:

$$\Pr(y_i \mid x_i, A_i = 0) = 1 - \psi_i = \frac{\Gamma(y_i + \alpha - 1)}{y_i! \Gamma(\alpha - 1)} \left(\frac{\alpha - 1}{\alpha - 1 + \mu_i i}\right)^{\alpha - 1} \left(\frac{\mu - 1}{\alpha - 1 + \mu_i}\right)^{y_i}$$, where $\mu_i = \exp(x_i \beta)$

Finally, the probabilities of zero and counts for those not zero are mixed together. The overall probability of a zero count is estimated as follows:

$$\Pr(y_i = 0 \mid x_i, z_i) = \psi_i + \{(1 - \psi_i) \times \Pr(y_i = 0 \mid x_i, A_i = 0)\}$$

The overall probability of an outcome other than zero is:

$$Pr(y_i = k \mid x_i, z_i) = (1 - \psi_i) \times Pr(y_i = k \mid x_i, A_i = 0)$$

Finally, the following equation estimated the expected counts among those without a zero:

$$E(y|x,z) = [0 \times \psi] + \{\mu \times (1- \psi)\} = \mu (1- \psi)$$

APPENDIX C

In this appendix, I review the strategies behind the analysis of the types of facilities and operators most responsible for Texas oil and gas venting and flaring practices in 2012. In essence, this appendix provides more details about the methods and findings underlying the research presented in section 4.

C.1 Research Method

C.1.1 Units of Analysis, Population, and Sample

This study involves all producing Texas oil and gas extraction facilities that submitted their monthly production and disposition report in 2012 that are within a mile of a Census block group with at least one American Community Survey five-year summary file block group estimate publicly released, as in Appendix B. In addition, this study also involves the companies with direct ownership of the oil and gas extraction facility (i.e., the operator). In 2012, there were 4,713 different operators in control of producing oil and gas extraction facilities.

C.1.2 Data Sources

In addition to the five different sources described in Appendix B, this study also relies on the following three sources: (1) additional Texas Railroad Commission datasets, (2) United States Energy Information Administration Interstate and Intrastate Pipeline Shapefile, and (3)

Corporate Structure Information on LexisNexis and Google, and (4) restricted American Community Survey 2010-2014 microdata available to approved researchers at a Federal Statistical Research Data Center.

C.1.2.1 Additional Texas Railroad Commission Datasets

C.1.2.1.1 Organization Report (P-5)

The Texas Railroad Commission Organization Report (P-5) dataset provides information on all organizations that have completed form P-5 required to legally engage in the oil and gas extraction industry business in Texas. Since 1981, organizations directly involved in oil and gas activities in Texas, including organizations involved in drilling, operating, or producing any oil or gas well, are required to file an organization report, Form P-5. This dataset is ideal because, to my knowledge, it is the only dataset that provides researchers with the capacity to link production and disposition at individual gas wells to specific operating companies.

C.1.2.1.2 2012 Inspection Extract

An extract of all inspections conducted by the Texas Railroad Commission in 2012 was received on June 25, 2016. This is an ideal dataset because it provides the most comprehensive information on inspection activities and when facilities violate state regulations. Since the state (not the federal government) is primarily responsible for regulating oil and gas extraction facilities, state regulatory activity is critical to the analysis.

C.1.2.1.3 2012 Permit Extract

An extract of all venting and flaring permits granted by the Texas Railroad Commission in 2012 was received on August 10, 2015. It includes information regarding approved flaring permits. This is an ideal dataset because it is maintained by the agency responsible for approving and tracking permits to vent and flare gas in Texas.

C.1.2.2 United States Energy Information Administration Intrastate and Interstate Natural Gas Pipeline Shapefile

A shapefile of the natural gas interstate and intrastate pipelines as of January 1, 2012 is publicly available to be downloaded at www.eia.gov/maps/layer_info-m.cfm. This dataset was collected by the EIA from the Federal Energy Regulatory Commission (FERC). This dataset is ideal because it provides the most extensive map of all natural gas pipelines in the continental United States. Like the Census TIGER/Line shapefile, this shapefile datum is NAD83.

C.1.2.3 Corporate Structure Information on Lexis Nexis and Google

The Texas A&M University Sociology Department Graduate Research Award supported an outstanding undergraduate student, Garrison Reed Barrilleaux, to collect corporate structure information on the operators identified in the Texas Railroad Commission Organization Report Form. First, using the operator names listed in the Texas Railroad Commission Organization Report Form, the student identified operators listed in the LexisNexis Corporate Affiliations

Database. Then, operators not identified in LexisNexis were searched on Google. All companies that could not be found on Lexis Nexis Corporate Affiliations that were found on Google were identified as private companies. The operators neither identified through Google or Lexis Nexis Corporate Affiliations are assumed to be small private companies or trusts without a multilayered subsidiary form.

C.1.2.4 Restricted American Community Survey, 2010-2014, Microdata

Restricted American Community Survey microdata was used to better quantify the remote communities surrounding facility locations.

C.1.3 Connecting Texas Railroad Commission Datasets

In addition to connecting the Texas Railroad Commission Datasets as described in *Appendix B,* the following steps were also taken. First, I parsed out and connected the Organization Report dataset to the production data dump using the operator number. Then I connected both the permit extract and inspection extract to the production data query dump using the district number, lease name and operator number.

C.1.4 Connecting Texas Railroad Commission Information with Other Datasets

To connect facility points to the nearest pipeline, I build upon the Geographic Information System described in appendix B. I started by adding the 2012 United States Energy

Information Administration Interstate and Intrastate Natural Gas Pipeline shapefile to the geodatabase and projecting it to North American Dam NAD83 State Plan Texas Central FIPS 4203 Coordinate System. Then, I used the nearest distance tool to find the nearest distance (in feet) between facility wellbore surface locations and pipeline established as of January 1, 2012.

To connect restricted Census microdata to public data, I first used population weights and individual and household responses to develop block group-level counts. Then, using block group identifiers, I connected Census block group estimates to facility identifiers. Next, I aggregated the characteristics of block groups within one mile of the facility location. Finally, I developed summary statistics, such as counts, percentages and medians, to quantify the characteristics of communities within one mile of each facility.

C.1.5 Data Analysis

This research uses a two-part/hurdle model in order to determine correlations between facility and operator characteristics and both (1) whether, among all producing oil and gas extraction facilities, the facility vented or flared (i.e., participation), and (2) the venting and flaring rate among facilities that vented or flared (i.e., magnitude). The final model accounts for the clustering of standard errors by facility operator. A two-part model accounting for the clustering of standard errors by facility operator was chosen over a multi-level model for two reasons: (1) because there is not enough variation at level one to run a multi-level regression model, and (2) because multi-level regression model outcomes are very similar to regression model outcomes that account for the clustering of standard errors. Using Stata's vce (cluster) command, I use Huber's (1967) formula to produce consistent standard errors, even though the data is clustered. To ensure that operators with many facilities are not under sampled, clustered sandwich variance estimators were produced rather than simply sampling one facility for each operator.

C.1.6.1 Participation Generalized Linear Model

The first part of the model (i.e., the participation model) investigates the direct effects of lease and operator characteristics on whether or not the lease vents or flares using the following equation:

$$\log\left(\frac{\varphi_{1j}}{1-\varphi 1_j}\right) = \gamma_0 + \sum_{k=1}^{K} \beta_k\left(M_{kj} - \overline{M_{kJ}}\right) + e_j, \text{ where } e_{itj} \approx \text{N}\ (0, \sigma_e^2)$$

In the full participation model above, φ_{1j} denotes the probability that lease j vented or flared; γ_0 denotes the average log odds that a lease will vent or flare; β_k is the corresponding coefficient that represents the direction and strength of the explanatory variable (k is the number of variables at the lease-level); M_{kj} is the observation of the explanatory variable k for lease j, and $\overline{M_k}$ is the mean of the explanatory variable k; e_j represents the random error, which is assumed to be normally distributed with a mean of 0 and variance of σ_e^2.

C.1.6.2 Magnitude Generalized Linear Mixed Model

The second part of the model (i.e., the magnitude model) investigates the direct effects of lease, and operator characteristics on the venting or flaring rate for leases that vented or flared gas using the following equation:

$$\log\left(E\left[\varphi_{2j} \mid \varphi_{2j} > 0\right]\right) = \gamma_0 + \sum_{k=1}^{K} \beta_k\left(M_{kj} - \overline{M_k}\right) + e_j, \text{where } e_j \approx \text{N}\,(0,\sigma_e^2)$$

In the full magnitude model above, φ_{2j} denotes the venting or flaring rate at lease j; γ_0 denotes the average venting or flaring rate of all leases that vented or flared; β_k is the corresponding coefficient that represents the direction and strength of the explanatory variable (k is the number of different explanatory variables in the model); M_{kj} is the observation of the explanatory variable k for lease j, and $\overline{M_k}$ is the mean of the explanatory variable k; e_j represents the random error, which is assumed to be normally distributed with a mean of 0 and variance of σ_e^2.