Environmental Justice and Coasian Bargaining: The role of race and income in lease negotiations for shale gas *

Christopher Timmins, Duke University
Ashley Vissing, University of Chicago

February 11, 2017

PRELIMINARY AND INCOMPLETE
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Abstract

With the dramatic growth in U.S. shale gas development over the last decade (particularly in populated areas), lease negotiations have become an important part of the energy landscape, and constitute one of the potential sources of benefit for homeowners. The bargaining process associated with the transfer of mineral rights from lessor to lessee shares many features of a classic Coasian bargaining framework. If bargaining were Coasian, it would reduce the need for costly government oversight of the leasing process. Using a unique combination of data sets, we test for whether the bargaining process exhibits characteristics of Coasian efficiency in one of the most active shale gas counties in the U.S. - Tarrant Co., Texas. Our results show that an important determinant of willingness-to-pay for avoiding shale gas development (income) does indeed affect bargaining outcomes, suggesting Coasian efficiency. However, we also find similar results for ethnicity and race. Importantly, we also find that many of these disparities can be explained by language. The fact that we find significant differences in lease quality across racial and ethnic groups, and can explain some of those differences with a measure of linguistic isolation, suggests an environmental injustice interpretation.

Keywords: Shale Gas, Hydraulic Fracturing, Mineral Rights, Lease Negotiation, Coasian Bargaining, Environmental Justice

JEL Codes: Q400, Q51, Q580, K320

*Timmins (christopher.timmins@duke.edu) - Department of Economics, Duke University, PO Box 90097, Durham, NC 27708 and Vissing (abvissing@uchicago.edu) - Department of Economics and the Energy Institute at the University of Chicago (EPIC). We thank seminar participants the PERC, NBER, UCLA, Colorado School of Mines, the National University of Singapore, and Pennsylvania State University for their helpful comments. All remaining errors and omissions are our own. We also thank the personnel at the Texas Railroad Commission and the Tarrant County Appraiser Office for guidance in collecting the well and housing/parcel data.

1 Introduction

Natural gas stored in tight shale formations has grown to become a major source of US energy supply. Facilitated by investments in technological innovations in large-scale hydraulic fracturing and horizontal drilling, large quantities of minerals that were otherwise inaccessible are opened up to development. In addition to expanding domestic US energy supplies, this growth has increased the income of households owning the mineral rights, both in rural and urban regions. However, these benefits are accompanied by costs external to the production process, including higher levels of air pollution from drilled wells,[1] noise, road damage, air pollution and accidents associated with increased truck traffic to and from the well site,[2] and the potential for soil or water contamination caused by radioactive salts and metals or chemicals that are used to the treat the wells,[3] among other unknown risks. Under the US legal structure, homeowners are protected from these external costs in one of two ways. First, ordinances are passed (at the municipal, state, and federal levels) that restrict activities at various stages of the drilling and production phases. Second, homeowners can negotiate for protections through the terms written into the lease agreements they sign, which transfer mineral rights to operators who then develop the minerals on behalf of the homeowner. Our paper explores the efficient and equitable distribution of landowner protections in privately negotiated mineral rights leases and the efficacy of private lease negotiations as a regulatory substitute for local ordinances.

Oil and natural gas lease negotiations that transfer privately owned mineral rights, in most states, are largely unregulated, yet they play an important role in the *de facto* regulatory process. It is therefore reasonable to ask how the outcomes of the lease negotiation process perform when measured against criteria typically ascribed to an environmental rule or regulation - in particular, efficiency and equity. To begin, we frame the private lease negotiations in the context of Coasian bargaining to test whether the negotiated outcomes are efficient. Coasian bargaining (Coase 1960) asserts that, in the absence of transaction costs and in the presence of well-defined property rights, producers and recipients of an externality will come to an efficient agreement about the quantity of externality to be generated. We capture efficiency in the private lease setting by analyzing whether variation in lease protections can be explained by differences in household income, approximating households' willingnesses-to-accept future drilling externalities.[4] Our hypothesis assumes that higher-income landowners have a corresponding higher willingness-to-pay to avoid polluting activities, and firms respond to landowners' preferences by offering them leases with greater royalties and bonuses and more landowner protections through clauses that restrict firm behavior. We then test whether the contracting outcomes are equitable by asking whether households' racial and ethnic

[1] **?**, **?**, **?**.

[2] **?**, **?**, **?**.

[3] **?**, **?**, **?**.

[4] Existing analyses explore the role of recipients' levels of education and incomes driving polluters' decisions, although the relevant factors are not limited to these alone (**?**, **?**). These studies find evidence that, for example, polluters pay less compensation to poor communities. If these communities have a lower willingness-to-pay to avoid pollution, this may be an efficient outcome.

characteristics explain the negotiated landowner protections included in some leases (or absence, thereof).[5] Controlling for factors that potentially affect willingness-to-accept pollution, like income, we test whether minority households sign leases containing fewer landowner protections, suggesting an environmental injustice in the presence of negative, future drilling externalities.

The second piece of our analysis addresses whether the additional legal restrictions, like lease clauses that protect landowners and their property, effectively mitigate poor drilling practices; i.e., is there a real effect on health and welfare from inequitable lease terms? Effective lease terms should be increasingly important as state-level legislation diminishes the jurisdiction of municipalities to directly regulate local drilling behavior, as in the case of Texas House Bill 40 passed in November 2014. State regulators do not restrict noise, traffic, and complete surface restoration, nor do they stipulate pre-drilling water and air pollution tests, among other drilling behaviors. However, these are features of the industry potentially regulated through more restrictive lease clauses or local ordinances, depending. The second piece of our analysis asks whether more landowner protections in leases lead to fewer future drilling complaints or violations, thereby substantiating the leases as substitutes for specific local statutes.

The oil and natural gas leasing market is comprised of both private landowners negotiating contracting terms and local ordinances that guide firms' future drilling and production behavior. This unique setting allows us to explore questions of efficiency, equity, and efficacy of privately negotiated bargaining outcomes in the presence of lower transaction costs.[6] Further, our data describe leasing outcomes in an urban/suburban region of Texas, which includes areas newly opened to well development. Cities are more likely to regulate drilling behavior locally; however, cities are increasingly restricted by the authority of states,[7] rendering the need for more protective leasing agreements to substitute specific statutes. In our data, we observe when and where individual leases are signed, passage of city-level local ordinances along with coded ordinance contents, and oil and gas well violations and complaints at the Census tract level. Further, our constructed data allows us to explore the relationship between specific contracting terms and the household characteristics for a large set of individually negotiated leases. In total, our constructed data allows us to draw empirical connections between leasing, municipal ordinances, and drilling violations in a way that captures the potential distributional consequences of fewer drilling restrictions.

Typically, oil and natural gas leases are comprised of royalty payments that begin once the wells are producing oil or natural gas,[8] a one time fixed bonus payment that is received at the time the

[5] We control for firm identity by estimating our models with firm-level fixed effects.

[6] Based on our understanding of the industry, the leasing phase is relatively low cost compared to drilling a well and producing gas from the firms' perspectives. Landowner costs hypothetically increase if they decide to involve an attorney or participate in a community-level negotiation.

[7] As mentioned above, the state of Texas restricted "home rule" by passing House Bill 40 in response to a drilling moratorium passed in Denton County, Texas.

[8] Royalties in Tarrant County Texas, our area of study, range from 18% to 25% of the profits from the future well that is pro-rationed across all of the minerals from which a well is extracting. **How much can a typical lessor hope to make?**

landowner signs the lease,[9] and the contract duration (primary term length),[10] among other standard clauses defining the temporary relationship between landowners and operators. In addition to standard legal clauses, leases may include auxiliary clauses that restrict operator behavior; these include noise restrictions, required surface restoration post drilling, or required environmental testing or standards. We have quantified whether leases contain clauses to protect landowners, along with measuring royalties and term lengths. We pair these lease characteristics with data describing the location of minerals, negotiating parties, and the households' characteristics including measures of income, race, and ethnicity.

A broad question in environmental economics is whether higher willingnesses to accept payments from recipients affects where polluters choose to locate, and whether such outcomes are, in fact, efficient. In particular, the result of an efficient Coasian bargaining process can lead to an inequitable outcome, whereby certain groups (i.e., poor and minorities) are disproportionately exposed to an environmental harm. We explore whether certain groups disproportionately sign leases containing fewer landowner protections by estimating a set of Seemingly Unrelated Regressions whereby the outcomes of interest are different measures of landowner protections. Using micro-level data that describes a household's income, race, and ethnicity, we analyze the relationship between these characteristics and the outcomes of a household's lease negotiation. Evidence that negotiated lease terms vary systematically with determinants of willingness-to-accept on the part of homeowners (e.g., income) is consistent with efficient Coasian bargaining. By controlling for a household's income, we better isolate the relationship between race and ethnicity and negotiation outcomes. Evidence that race or ethnicity matters for the negotiated lease outcomes suggests the possibility of discrimination, which is an outcome of interest in the context of environmental (in)justice, and we find that minority households are less likely to sign leases with more landowner protections. We then use our data to explore how the relationships differ when households are linguistically isolated or from different income brackets. Demonstrating that aspects of this dependence on race or ethnicity can be explained largely in terms of English-speaking ability (in the case of Hispanics) suggests that bargaining outcomes may reflect an important information asymmetry, suggesting that the observed outcome may be far from efficient. These results raise questions about the need for government regulation of the bargaining process (e.g., uniform lease terms), or greater regulation of environmental harms with "public" tools (i.e., stronger municipal ordinances).

We then proceed to evaluate whether local ordinances effectively deter bad drilling practices and also whether leases are effective substitutes for more uniform regulations. In particular, using tract-level measures of drilling violations and complaints, we estimate relationships between ordinance passage or more restrictive leases and the future violation frequencies. In both settings, we find that restrictions are negatively correlated with future drilling violations and complaints, thereby

[9] While leases are public data, bonuses are not required to be reported, and as a consequence, we only observe roughly 1.6% of leases with bonuses.

[10] Ranging from 12 to 60 months, the primary term length limits the time a firm has to drill a well and begin producing oil or natural gas before the mineral rights automatically revert back to the landowner. Leases may also include a primary term extension that usually stipulates that firms pay the landowner an extension bonus if the extension is exercised.

serving as potential deterrents. We also show that minorities tend to live in areas with more local ordinances (in relatively more urban areas of Fort Worth), while areas with more restrictive leasing are less likely to pass drilling ordinances. In light of recent litigation restricting "home rule," we use our empirics to motivate more uniform leasing standards as a reasonable substitute to individual municipalities passing local ordinances. Further, a more uniform leasing standard would equalize landowner protections across minority and non-minority households as well as across urban, suburban, and rural regions experiencing an influx of drilling activity.[11]

This paper proceeds as follows. Section 2 reviews the two relevant literatures that this paper draws upon: Coasian bargaining and environmental justice. Section 3 describes the relevant institutional and legal frameworks surrounding shale gas development in Texas. The specifics of the legal structure surrounding lease clauses, lease negotiation, and municipal regulation play a particularly important role in our conclusions. Section 4 describes our data, which are drawn from a novel source of information about the outcomes of lease negotiations and proprietary data on housing transactions combined with publicly available data on the race and income of homeowners. Section 5 motivates our empirical approach with a brief discussion of the Coase Theorem and environmental justice. Section 6 describes our empirical modeling strategy and summarizes results. Section 7 concludes with a discussion of our results with a particular focus on policy implications.

2 Literature Review

In this paper, we explore the determinants of the bargaining outcome associated with the mineral leasing rights required for shale gas development. In particular, we explore whether the leasing process exhibits characteristics consistent with efficient Coasian bargaining, or whether there are other factors (in particular, factors that could be associated more directly with race and language) that play a role. Our work is therefore related to the literatures on the Coase Theorem, environmental justice, and the health impacts of exposure to shale gas development.

2.1 Coasian Bargaining

The literature on the Coase Theorem is extensive; we do not attempt to summarize it here but rather refer the reader to one of several reviews (**?**, **?**, **?**, **?**). Coasian bargaining theory states that, in the absence of transaction costs and under well-defined property rights, parties will bargain to an efficient outcome in the presence of externalities. This will place the resource in question into its highest valued use, regardless of the initial allocation of property rights.

The size of the compensation paid by a polluter to a victim with property rights should depend upon both the victim's willingness to accept compensation in exchange for tolerating the externality and the magnitude of the externality. Bargaining power is also likely to have an effect -

[11] Equalizing protections across urban, suburban, and rural regions is arguably more effective than a system with "home rule" since local ordinances only apply to incorporated areas, which does not include more rural regions, and the local ordinances are significantly variable in landowner protections across cities based on the data we have assembled.

residents who are better able to organize themselves are better able to obtain outcomes favorable to their community. **?** analyze the compensation offered by landfill operators to community leaders in exchange for being allowed to operate a nearby facility in the context of a Coasian bargaining process. Compensation packages of this sort became popular in negotiations between landfill developers and communities in the late 1980's. Using data on host fees paid by 104 largest privately owned solid waste landfills in 1996, the authors examine a number of characteristics that could potentially make bargaining payments larger. The primary factors that are found to affect the size of payments include citizen participation in negotiations, experience hosting a landfill, state mandates for minimum host compensation, and industry concentration (implying oligopoly rents and greater ability to pay). The authors find some indication of efficiency in the bargaining process, in that some measures of the severity of the externality (i.e., sludge and tires) do affect the size of the payment. However, they also find contradictory evidence in that lower host fees are paid the closer is the nearest subdivision to the facility.

In a study of the expansion plans of commercial hazardous waste facilities, **?** tests three theories for why exposure to environmental harms might vary with race: (i) pure discrimination, (ii) differences in willingness to accept payment for loss of environmental amenities linked to income or education, and (iii) propensity for collective action. The latter two explanations have connections to the theory of Coasian bargaining. In particular, firms will avoid locations where residents require a greater compensatory payment. They will also avoid locations where a tendency towards collective action will make payments more likely. It can be difficult to break the simultaneity between neighborhood characteristics and the presence of an environmental harm. Do nuisances locate in minority neighborhoods in an effort to avoid compensatory payments, or do neighborhoods become increasingly minority following siting decisions? **?** overcomes this problem and tests the hypotheses described above by using information on the planned capacity decisions of commercial hazardous waste facilities (i.e., looking to see how facilities' plans to expand vary with neighborhood attributes). Because those expansions have not yet taken place in the data, it is impossible for observed neighborhood demographics to have been determined by them. **?** finds that neighborhoods (zip codes) targeted for expansion in 1987-1992 had non-white population of 25% compared to 18% not targeted. Looking more specifically at the mechanism underlying this disparity, differences in the likelihood of raising firms' costs via collective action (measured by voter turnout) offer the best explanation, rather than pure discrimination or a simple Coasian bargaining story.

2.2 Environmental Justice

Analysts typically date the emergence of the environmental justice movement to a set of protests following the selection of a landfill site in the predominantly African-American community of Warren County, North Carolina in 1982 for the disposal of PCB's (**?**). These protests were organized, in part, by the United Church of Christ Commission for Racial Justice, which went on to produce the first national-level analysis documenting the correlation between race and pollution (**?**). These protests also prompted the U.S. General Accounting Office to carry out a study in 1983 showing that landfills were disproportionately located in Black communities, specifically in the U.S. South. ? and ? were followed by a series of papers that demonstrated the correlation between race, poverty, and exposure to environmental harm (?, ?, ?, ?, ?). These studies found a significant disparity in proximity by race (even after controlling for income), local land use patterns, the percentage of employees in manufacturing, population density, and other relevant variables. Other analyses were more specifically focused on risk-based measures of pollution exposure, but found similar results (?, ?, ?, ?, ?). In 2007, the UCC updated its 1987 analysis using information on hazardous waste facility locations and demographic data from the 2000 Census, finding that poor and minority groups were even more heavily concentrated around hazardous facilities than had been previously thought.

Analyses documenting the correlation between environmental harms and disadvantaged status (i.e., race and income) form the first strand of the environmental justice literature. A second strand seeks to explain the mechanism behind those correlations (?). Understanding that mechanism is crucial for the design of effective policy. One story explains correlations as the result of the siting of nuisances, paying particular attention to the demographics at the time of siting (?, ?, ?, ?). A second story focuses instead on residential sorting, i.e., the tendency for disadvantaged groups to move into polluted areas where residences are less expensive ("coming to the nuisance").[12]

There are a number of papers that directly compare the siting and sorting explanations. ? show that, over a 30-year period, the correspondence between polluting facilities and minority communities in Los Angeles was based primarily on a pattern of disparate siting of facilities in existing communities of color, rather than on geographic shifts in these populations. ? find strong evidence of correlation between risk-based measures of exposure and race (even after controlling for income) along with evidence of disproportionate siting. However, they find no evidence of sorting behavior. ? demonstrate that the model used in these papers to identify the sorting process is fundamentally unidentified; imposing structure on the model to achieve identification, they find strong evidence in favor of the sorting hypothesis.

We are not aware of any existing analyses of shale gas development from the perspective of environmental justice. Our paper seeks to document the existence of correlation between race, income and lease terms that may be conducive to exposure to environmental harms. Our analysis of linguistic isolation explains the mechanism behind observed correlations and has an environmental justice interpretation particularly related to siting and the breakdown of Coasian bargaining.

2.3 Health Impacts of Shale Gas Development

Many of the most important ramifications of exposure to shale gas development have to do with health impacts. To date, there have only been a handful of studies of these impacts. ? details potential health impacts to the brain & nervous system, kidneys, endocrine system, and the immune and cardiovascular systems, as well as increased risk of cancer or mutation from exposure to the chemicals used in fracking. ? compares cancer risks from air emissions inside and outside

[12] See, for example, ?, ?, and ?.

of a one-half mile buffer around wells in Colorado, with a focus on benzene. **?** use case-study interviews to analyze health impacts on humans and animals living near shale gas development, finding common reports of respiratory, gastrointestinal, dermatological and neurological problems.

? studies birth outcomes to mothers of singleton infants located in close proximity to wells in Pennsylvania between 2003 and 2010. Using a difference-in-differences strategy for identification, she finds dramatic impacts for mothers who reside within 2.5km of a well (relative to those in a control group consisting of mothers in the 2.5-5km distance range). Specifically, she finds an increased risk of low birth weight (+1.36 percentage points) and APGAR score less than 8 (+2.51 percentage points). An examination of household water source suggests that these impacts are driven by air pollution or stress from increased local activity (e.g., noise and light pollution), and falsification tests rule out alternative explanations besides drilling. Recent research by **?** and **?** find evidence of links between exposure to hydraulically fractured wells and drinking water quality.

3 Legal and Institutional Detail

The following sections describe the technological developments driving the natural gas industry's increased productivity and the institutional details behind the regulation of the industry. Over the past 20 years, combined horizontal drilling and large-scale hydraulic fracturing technology has evolved to allow access to natural gas contained in tight-shale formations spread over a large area while requiring fewer well pads. Further, these technological developments have increased activity in urban plays, literally bringing drilling into suburban households' backyards. Regulation guiding industry practices, however, has been largely crafted for activity in less densely populated areas – the more common setting for natural resource extraction. We describe the technological innovations and regulatory structure relevant to our story of Coasian bargaining and environmental justice.

3.1 Hydraulic Fracturing and Horizontal Drilling

The process of hydraulic fracturing enables firms to extract natural gas from tight shale formations by artificially stimulating the strata. This increases the flow of natural gas within the shale, resulting in its eventual release and collection at the wellhead. Horizontal drilling techniques allow firms to drill wells accessing minerals located within a large radius surrounding the wellhead. Fewer drill sites are therefore required to reach a larger subsurface area and better access is provided for broad resource deposits. Horizontal drilling therefore allows firms to extract large quantities of natural gas from a smaller surface footprint, facilitating extraction from areas of higher population density. As these unconventional drilling techniques have been adopted by the industry, individuals in (sub)urban areas have subsequently found themselves to be parties to negotiations with operators over mineral rights leases.

3.2 Texas Railroad Commission and State-Level Regulation

The Texas Railroad Commission (TRC) oversees the majority of the oil and natural gas industry in the state of Texas, which includes the approval of permits to drill wells.[13] However, prior to permit approval, firms must first amass a large and sufficient mineral estate acreage that is spaced far enough away from existing well infrastructure to be approved and permitted by the TRC.[14] Mineral estate acreage is obtained by signing leases with mineral rights owners. Households signing leases with natural gas firms or "landmen" are tasked with weighing the trade-offs between future income derived from natural gas extraction from their mineral estate with that of the potential known and unknown risks of living near an active well. Once a well is permitted, the operator has two years to begin drilling the well before the permit expires.

The TRC's jurisdiction regulating the industry extends to the drilling and production phases; however, the TRC does not regulate noise, traffic, or well pad appearance, nor does it require air pollution testing. By law, operators have access to surface water to be used to treat the well, and chemical disclosure is restricted to only the non-proprietary chemicals used to fracture a well.[15] In general, the dis-amenities experienced by households from nearby shale gas activities are unregulated by state and federal entities and are folded into the private leases signed between them and firms.

More specifically, federal and state regulators generally do not have direct jurisdiction over the private contracts drawn between landowners and parties interested in leasing land for exploration and production of oil and natural gas. Higher-level regulation is limited to royalty payments (stipulating when they are to be paid), the required information that must be provided (and that which can be requested) by firms, notification upon re-assignment of leased rights, and determining the consequences of delinquent payments. In addition, the TRC has jurisdiction over enforcing and undertaking remediation from undue negligence on the part of firms and broadly enforcing the protection of ground and surface water from contamination caused by the industry. However, the TRC's jurisdiction over the leases signed between households and firms, and subsequently, the protection of households while a well is drilled and after production ends is limited, and a well-informed household may negotiate more comprehensive contracts with leasing firms to protect their interests beyond the minimal coverage of the law.

3.3 Municipal Regulation

Local regulation in Texas is an interesting feature of the legal structure whereby localities can exercise home rule, passing ordinances that restrict activity within their jurisdiction. In the

[13]The Texas Railroad Commission has jurisdiction over the "exploration, production, and transportation of oil and gas prior to refining or end use," and the TRC executes its jurisdiction by enforcing rules written in the Texas Administrative Code, Chapter 3.

[14]Texas Administrative Code, Chapter 3, Rules 3.37 & 3.38.

[15]Texas Administrative Code, Chapter 3, Rule 3.29. All chemicals and quantities used are reported via the Chemical Disclosure Registry and publicly disclosed unless a component of the composition is considered a trade secret, and the trade secret component is omitted from public disclosure.

past, the oil and natural gas industry has focused most of its energy on drilling in rural areas; however, firms combining large scale hydraulic fracturing and horizontal drilling techniques have increased access to tight-shale formations lying beneath urban areas, like that of the Barnett Shale, with less surface interference. As firms have increasingly begun exploiting regions like the Barnett Shale, more households have been exposed to drilling activity, and as a consequence, municipalities have passed local ordinances protecting properties within their jurisdictions. These local ordinances further restrict the activities of firms by requiring, for example, larger set-back distances, additional permits and fees, well construction restrictions, and additional environmental tests.

Local municipalities often employ land-use policy to restrict oil and gas development within their jurisdictions. Municipal governments are able to enact local ordinances that stipulate types and locations of land use and permissible damage for the purposes of protecting public health and welfare. Local ordinances are rendered preempted (or essentially invalid) if state-level legislation has passed that limits local power directly (expressed preemption); the state rules already occupy a field (implied preemption); or if they conflict with existing state laws (Urban Lawyer, 545-546). The last of these usually restricts local zoning ordinances that loosen state rules, but it can uphold those that strengthen them.

3.4 Lease Components

Signing a comprehensive leasing document is important for households protecting their rights while they are royalty interest holders.[16] In particular, lease terms can compensate for the absence of state or municipal regulations. Leasing agreements contain a set of primary clauses common to all leases drawn in the industry and sets of auxiliary clauses that are negotiable between lessors (mineral rights owners) and lessees (exploration and oil and natural gas production firms). Primary clauses include a careful description of the minerals leased to the lessee; information about the royalty payments owed to the lessor once the well begins to produce in paying quantities; the duration of the lease, or primary term; and opportunities for extension once the primary term has expired.

Auxiliary clauses are written into the agreement to protect one or both of the parties, but may not be included in all leases. Negotiators may draft surface damage clauses ensuring that the operator restores the surface to a condition agreed upon by both negotiators once production is complete; environmental clauses requiring producers to perform regular environmental quality tests on the surface and ground water or soil samples; and pooling restrictions ensuring that the leased land value is not diluted in terms of royalty payments by being grouped into an unnecessarily large acreage, to name a few.

3.5 Split Estate

Up to this point, we have assumed the signer of the lease is the household, or surface-rights owner; however, the state of Texas allows the mineral estate to be split (or "severed") from the

[16]The risks are less when the property lies in a municipality having passed local ordinances written to protect lessors' rights.

surface estate. The individual signing a lease with a natural gas firm may not, therefore, be the individual living in the house positioned on the surface estate. As early as 1953, Texas courts declared that landowners may reserve mineral rights and the oil and gas contained as in the case Benge v. Scharbauer [259 S.W.2d 166 (Tex. 1953)], thereby enabling the mineral estate to be severed from the surface estate (?).[17] In the event of severance, the mineral estate dominates in terms of exploration and extraction, and the mineral lessee assumes the same rights owed to the mineral estate owner since the leasing document is perceived as a temporary transference of ownership.[18] Colloquially, the owner of the mineral estate may lease the minerals to third parties for exploration, but the law only requires that the lessee (i) notify surface owners of the "intent to explore and drill;" (ii) have access to as much land as is necessary to explore and drill; (iii) be able to remove trees and fences to make way for well and equipment; (iv) be able to take up to one acre of land for the well pad; and (v) be able to erect pipelines to transport the natural gas off the property (?).[19,20]

As an independent entity, the mineral estate may exercise its rights without consulting the surface estate owners. Subsequently, a firm leasing the mineral rights for purposes of oil and gas exploration and extraction need only negotiate with the mineral estate owners whether they also own the surface estate or not. The owners of the mineral estate may exercise their rights without consulting the owners of the surface estate, and they are only required to inform the surface estate when drilling is imminent on their property due to legislation passed in 2007 (?).[21] Additionally, the mineral estate may use as much surface water from the leased land as is reasonably necessary to carry out operations, given that the use is not wasteful, and it may inject wastewater into sub-surface formations.[22,23] Moreover, the mineral estate does not accept responsibility for the full restoration of the property,[24] nor is it required to pay surface damages as long as the damage is not unreasonable.

[17] A grant or reservation of minerals by the fee owner affects a horizontal severance and the creation of two separate and distinct estates: an estate in the surface and an estate in the minerals [Acker v. Guinn, 464 S.W.2d 348, 352 (Tex. 1971)] (?).

[18] If the minerals are not reserved at the sale date, the mineral estate automatically goes to the buyer along with the surface conveyance (?).

[19] Under the dominance of the mineral estate, there are five interests including the right to develop the mineral estate, or ingress and egress, which includes exploration; to lease; and to receive bonus payments, delay rentals and royalty payments (?).

[20] There are three exceptions to the dominant mineral estate including excessive use of land in exploration and operation activities to access the minerals, unnecessarily injuring the surface, and not accommodating the existing surface use, the latter more formally entitled the Accommodation Doctrine (Letter of the Law, 1997).

[21] Texas Natural Resource Code, 91.703(a): Not later than the 15th business day after the date the commission issues an oil or gas well operator a permit to drill a new oil or gas well or to reenter a plugged and abandoned oil or gas well, the operator shall give written notice of the issuance of the permit to the surface owner of the tract of land on which the well is located or is proposed to be located.

[22] Warren Petroleum Corp. v. Martin, 271 S.W.2d 410 (Tex. 1954).

[23] Unless specified in the deed, the water rights fall to the surface owner but they are accessible with reasonable use by the mineral estate (?).

[24] Warren Petroleum Corp. v. Monzingo, 304 S.W.2d 362 (Tex. 1957).

3.6 Rights of Surface Owners

Texas has not passed a law protecting the surface estate, or a surface damage act, as has been passed in other states with prominent oil and natural gas industries (including New Mexico, Oklahoma, North and South Dakotas, and Montana). As mentioned above, surface owners are not owed any remuneration for the opportunity cost of the piece of their property that is lost during the drilling period, nor must they be paid for reasonable damages to the land caused by drilling. If there is any perceived misuse of the land by mineral rights owners, surface owners are responsible for proving unreasonable conduct, which does not include surface damage or inconvenience. Surface owners are marginally protected by the Accommodation Doctrine, which protects existing surface owner uses.[25]

In lieu of state regulation, and in some cases, local ordinances, lessors can negotiate a surface damage clause into the leasing agreement to protect the surface during production and ensure remediation after production ends. Otherwise, the surface estate may only claim and prove unnecessary damage through litigation. However, since the state of Texas does not require operators to negotiate with the surface estate independent of the mineral estate, a severed estate with a lease may not naturally include a surface damage clause. Property owners holding deeds to both the surface and sub-surface can negotiate surface damage clauses that might include complete restoration of the surface upon completion of the well and perhaps assign a property damage fee; however, among mineral estates, there is little incentive for a mineral estate owner to negotiate a surface damage clause with a potential operator. In the latter case, among severed estates, surface owners have little legal protection.

4 Data

We use a unique combination of lease, well activity, housing, and demographic data sets. This section details the sources of data and describes how certain variables are constructed. The data originate from several sources and are compiled for analysis by a series of matching techniques, primarily based on text strings.

Of primary importance are the well and lease data with which we describe the precise amount of well exposure and the types of leases signed at the transaction and appraisal dates observed in the housing data. We have also collected relevant housing transaction and appraisal data from the Tarrant County Appraiser District office and Dataquick, a national real estate data aggregator. Schooling data from the Texas Education Association, demographic information collected under the Home Mortgage Disclosure Act, and drilling, inspection, and violation data from the Texas Railroad Commission are used as well.

[25]Accommodation Doctrine: [W]here there is an existing use by the surface owner which would otherwise be precluded or impaired, and where under the established practices in the industry there are alternatives available to the [mineral owner] whereby the minerals can be recovered, the rules of reasonable usage of the surface may require the adoption of an alternative by the [mineral owner]. (Tarrant County Water Control & Improvement Dist. No. 1 v. Haupt, Inc., 854 S.W.2d 909, 911 (Tex. 1993)) (**?**).

4.1 Well Exposure

Well permitting data are used to construct a variable describing well exposure from the perspective of the household at the time of the appraisal. Well permitting information comes from two sources: the Texas Railroad Commission and DrillingInfo, a proprietary aggregator of drilling activity information. Exposure is tabulated at different distance buffers surrounding the house, and if an operator has begun drilling a well by the appraisal date, the well is included in the exposure variable. We tabulate exposure based on 500, 750, 1000, and 2000-meter buffers, and the calculation differentiates between wells that are permitted, spudded, and producing. The primary exposure variable used in our analysis is the count of wells that are producing within a 2000-meter buffer. Table 1 summarizes well exposure over time for the hedonic sample since well exposure is an important variable in that analysis. We observe a steady growth in shale gas development in Tarrant County between 2003 and 2013, and the exposure growth is evident through the increase in the count of wells located within a 2000-meter buffer (*Panel A*) and the decrease in distance to the nearest well (*Panel B*).

4.2 Lease Data

The lease and lease contents are a primary and unique source of data used to describe the outcome of the bargaining process conducted between two parties – the lessee (i.e., who is typically an operator or third party "landman") and the lessor (i.e., the owner of the mineral rights, who is also the owner of the surface rights in the case of a full estate).[26] Signing the lease conveys the interests of the mineral estate from the lessor to the lessee.

Signing a comprehensive leasing document is important for households protecting their rights while they are royalty interest holders. In particular, lease terms can compensate for the absence of state or municipal regulations. Leasing agreements contain a set of primary clauses that are common to all leases drawn in the industry, and may also contain combinations of auxiliary clauses that are negotiable between lessors (mineral rights owners) and lessees (exploration and oil and natural gas production firms). Primary clauses include a careful description of the minerals leased to the lessee, information about the royalty payments owed to the lessor once the well begins to produce in paying quantities, the duration of the lease (i.e., primary term), and opportunities for extension once the primary term has expired. Auxiliary clauses are written into the agreement to protect one or both of the parties, but may not be included in all leases.

We have collected data describing the terms of these privately negotiated lease contracts. In particular, we have data describing the primary clauses (i.e., royalty rate and lease term) of all natural gas leases negotiated in Tarrant County, Texas between 2000 and 2013. In addition to the primary clauses contained in the leasing agreements, we have also collected auxiliary clauses for one third of the sample. The data period for auxiliary clauses with a large enough sample size begins in 2006 and ends in 2011. Our specific sample was collected from the "Drilling Down Series"[27]

[26] Full estates are also referred to as fee-simple, or whole, estates.

[27] `http://www.nytimes.com/interactive/us/DRILLING_DOWN_SERIES.html`

published by the *New York Times* from 2011 into 2012. We scraped these data and then mined the files for words and phrases indicating the existence of specific clauses using an algorithm written in Python. This process is described in Appendix A. A list of these clauses and clause descriptions is included in Appendix B.

The full set of auxiliary lease clauses fall into several broad categories including strict legal requirements, clearer definitions of liability, additional environmental requirements, requirements for increased reporting by the lessee to the lessor regarding well activity, and restrictions on how a firm can access the mineral estate. A particularly important clause in Texas is the surface damage clause, which we capture by searching for phrases describing cleanup efforts and damage remediation. Mineral rights owners can negotiate a surface damage clause into the leasing agreement to protect the surface and use during production and ensure remediation after production ends. Surface owners are not owed any remuneration for the opportunity cost of the piece of their property lost during the drilling period or for reasonable damages to the land caused by drilling. If there is any perceived misuse of the land by mineral rights owners, surface owners are responsible for proving unreasonable conduct that does not include surface damage or inconvenience. Surface owners are somewhat protected by the Accommodation Doctrine, which protects existing surface owner use,[28] and surface owners can negotiate a separate addendum to the lease requiring surface protections.

Table 3 summarizes primary clauses (royalty rate and primary term length in months) along with the set of different auxiliary clauses that we use throughout our analyses.

4.3 Housing Data

In addition to the leasing and regulatory data, we use appraiser data describing the household attributes compiled from the Tarrant County Appraiser District (TAD) office and Dataquick, Inc.. TAD provides us with historical appraisal data from 2008 to the present in addition to a file delineating all transactions in Tarrant County. We use this data to construct a cross section of appraised values for each property that is observed being bought or sold. TAD also provides us with information on the house's water source (groundwater v. piped). We merge the TAD data with Dataquick, which serves as our source of loan information (lender name, loan amount, FHA loan). By merging appraisal data with transaction information from Dataquick, we are also able to incorporate demographic information of the house inhabitants at each appraisal date using the Home Mortgage Disclosure Act data, a match that will be described in more detail below.

The housing data is the nexus for several connections between our data sources. In particular, leases are merged to the housing data by address using various string matching methods, and the housing data is merged to the HMDA data by lender name, loan amount, and a geographic identifier.

[28]If there exist alternative extraction methods, then reasonable usage might require a change on the part of the lessee under the Accommodation Doctrine (**?**).

4.4 Home Mortgage Disclosure Act (HMDA)

To account for household demographic information in the regressions, including household income, ethnicity, and race, we merge the housing data to data collected in accordance with the Home Mortgage Disclosure Act (HMDA). This legislation was originally passed in 1975 and amended in 1989 to ensure fair and adequate lending and to limit discriminatory lending practices. We merge HMDA to the housing data by matching the tract, lender name, and loan amount across HMDA and Dataquick.

4.5 Violations

We obtained complaint data from Texas Commission of Environmental Quality (TCEQ) to use in the tract-level analysis relating lease quality to future well violation outcomes. The data describe complaints filed with the TCEQ including filing dates, whether the complaint is related to waste, or air or water quality, resolution date, and a location. We mapped each provided violation address to a tract and calculated the cumulative violations occurring in a tract before and after each of the leases is signed. The regressions in the analysis use the count of violations occurring in a tract after the lease is signed, along with the count per producing well located in the tract. These data are summarized in Table 2b.

4.6 Local Ordinances

Since the shale boom began in Tarrant County, several municipalities have passed local ordinances governing the oil and natural gas industry within their jurisdiction, strengthening the compliance requirements of operators permitting and drilling wells. The data describing local regulation are coded from reading each municipal ordinance governing the oil and gas industry, segmenting the rules into categories, and accounting for the thoroughness of the written rule. These data are then merged to the housing data by year of passage and city name such that we can estimate a model accounting for the mean value of a passed ordinance and, in some cases, the value of specific rules from the perspective of the household. The ordinance measures used in the analysis are summarized in Table 2c.

By establishing the relevant rules in the Texas Administrative Code, or the state-level rules, as a baseline level of regulation, several regulation categories have been defined and coded to represent how the local ordinances deviate from the state-level rules and increase the strength of regulations for operators drilling wells in the identified locations. Roughly 31 of the 33 cities in Tarrant County have an independent permitting application and set of restrictions that are in addition to the well permits issued by the Texas Railroad Commission, and 27 cities lie well within the boundary of Tarrant County. Cities increase restrictiveness in the technical standards of wells and well sites by requiring additional tests, writing more detailed rules, or specifying distance buffers for compliance. In addition, categories of regulations limiting externalities like traffic, noise, and most environmental standards (excluding some ground water regulation and hydraulic fracturing fluid disclosure) are not regulated under the Texas Administrative Code but are only found in local ordinances.

The stringency of the regulatory framework for each local ordinance is coded by sub-groups including noise, work hours, permitting, well and pit construction, fracturing restrictions, environmental testing, and financial security requirements. Within each sub-category, an index was calculated based on the number of total restrictions, distance buffers, and related costs, depending on the category. For example, cities often require fees when an operator applies for a well permit. Sub-categorizing the fees into permitting and other application fees, the fee index is weighted by the maximum value in each fee category along with that category's contribution to the total cost of permitting. Additionally, well set-back rules specify how far a well bore should be from a residence, other well structures, fresh water sources, or trafficked roads; we account for the variation in this rule across space by normalizing the specified distance with respect to the minimum and maximum distances and weighting each individual set-back rule using the total number of feasible set-back rules one locality can stipulate.[29,30]

4.7 Sample Description

The Coasian analysis begins with all properties that have transactions in our data period, 2003 to 2013, and landowners are observed signing leases after the transaction date; these are the properties where we are able to use information from HMDA to infer the race and income of the occupants at the time the lease was signed. In particular, we are able to match 117,453 transactions in Dataquick properties to observations in the HMDA dataset using loan amounts, lender names, and census tract identifications. Of those Dataquick observations matched to HMDA, 91,067 observations have race and ethnicity data. Among those matched properties, 33,146 are matched to leases that are signed after the transaction date. Among those leases matched to properties, we have the clauses written into those leases for 9,140 observations as described in the second panel of Table 2, which is the data sample we use for the Coasian analysis.

5 Environmental Justice and Coasian Bargaining

We motivate our explanation of the distribution of protective lease clauses with a brief discussion of the Coase Theorem and Coasian bargaining. The simplest version of the Coase Theorem states that, in the absence of prohibitive transaction costs and with well-defined property rights, parties will negotiate to an efficient equilibrium in the presence of an externality. Efficiency is defined either in marginal terms (i.e., the cost of the last unit of the externality borne by the victim is equal to the benefit of that unit of externality to the polluter) or in discrete terms (i.e., property rights will be allocated so that the resource in question is put into its highest value use).

[29] This normalizing technique is similar to the Resources for the Future analysis evaluating the disparity in regulation across states with active oil and natural gas industries (?).

[30] We have considered other strategies for indexing local ordinances, including factor analysis, but have concluded that it is more interesting to analyze the disaggregated set of rules in order to better understand which rules are more binding for operators.

In negotiations for the rights to shale resources, property rights are well-defined and lie with the mineral rights holder. A whole estate has a single owner for both the mineral and surface rights associated with the property. A split estate had different owners for the mineral rights and surface rights. Mineral leases are legally binding agreements between a lessor and a lessee that are enforced by U.S. courts, and many lease components are standardized within the industry. While lawyers may be involved in the negotiation process (helping to mitigate problems of asymmetric information), transaction costs to sign leases are likely to be low. As a consequence, we might expect the Coase Theorem to apply to lease negotiations that transfer mineral rights.

In particular, we identify all of the disamenities associated with proximity to drilling activity, which include (but are not limited to) air, light, noise, and water pollution (or the risk thereof), surface damage and alteration of the terrain. Some of these activities may be regulated by municipal ordinances and they may be privately "regulated" by clauses negotiated into individual leases. Because avoiding these activities is costly, the marginal value of producing disamenities through drilling a natural gas well is positive but decreasing for the operating firms. Added to the benefits are actual revenues that result from selling the natural gas extracted from the well.

In the lease setting, the landowner (who, for now, is assumed to also be the mineral rights holder) owns the property rights, and assuming the landowner faces a cost from disamenities, failure to negotiate implies that the well is never drilled. However, since the operating firms benefit from producing disamenities (via drilling a well), the firms are willing to compensate the landowners up to the point at which the marginal benefit to the firm is equal to the marginal cost experienced by the landowner. As a consequence of a negotiated level of produced disamenity, a Coasian surplus is generated and divided between the firm and landowner relative to their respective bargaining powers.

Analogously, in an equilibrium setting, firms derive a total benefit from drilling a well, extracting natural gas, and earning revenue from the sale of natural gas, and landowners experience a total cost to being located near to the drilling activity. However, landowners own the property rights and firms have a price they are willing to pay to compensate the landowners for their experienced disamenity. Under efficient Coasian bargaining, negotiators first maximize the bargaining surplus by choosing a level of disamenity that maximizes the difference between the total benefit of drilling (and generating disamenities) to firms and total costs to landowners. A separate negotiation subsequently divides the bargaining surplus between the negotiating parties. In our setting, the royalty split of future revenues from natural gas sales resembles the surplus split in the theoretical setting.

The equilibrium level of disamenity is determined by variables that affect the willingness-to-accept (WTA) in exchange for exposure to the disamenity. **?** refers specifically to income and education. We also include the spatial controls[31] and a dummy variable indicating that the house relies upon groundwater. Variables like income, land size, and water source might also influence

[31]We control for unobservable characteristics that may be similar for households located near to one another by including wellpad fixed effects. This should compensate for having fewer micro-level controls that describe the household size and prevalence of children and the elderly in the households for which we only have census tract-level controls.

bargaining power, which determines how the Coasian surplus is divided between the driller and the lessor in the setting of the royalty rate. We might also expect variables such as race and linguistic isolation to have an effect on bargaining power and the royalty rate. It is, however, difficult to think of a reason why, after controlling for income and other household characteristics, race and linguistic isolation should have an independent effect on the willingness to pay to avoid drilling disamenities, and finding evidence that it does suggests we are not in an efficient Coasian outcome (i.e., the disamenity is being determined by factors other than equating marginal costs and marginal benefits). We test this hypothesis explicitly in our empirical specification presented in Table 4.

6 Model Estimates

Below we present estimates that capture the relationships between household characteristics and the types of landowner protections negotiated into their leases. We then approximate the efficacy of both lease composition and local ordinances at deterring bad drilling behavior as measured by future violations at the tract and city levels, respectively. We use these estimates to better understand how lease quality is distributed across different racial and ethnic groups, suggesting environmental injustice in the leasing market, and to motivate policies that protect these landowners through homogenizing the leasing phase that precedes any drilling or production.

6.1 Analysis of Lease Terms

We conduct our analysis of lease clauses treating each as a separate bargaining outcome but allowing for the fact that clauses are negotiated as part of a single bargaining process. As such, we treat the equations describing the outcomes of each lease clause as a seemingly unrelated system of regressions. Results are described in Tables 4, 5, and 6, and we limit our analysis to lease signers who own their full estate (i.e., mineral and surface rights). Dependent variables are listed in the first row, and regressors appear in the first column. Regression coefficients describe the likelihood of each lease clause as a function of attributes of individuals who sign leases, house attributes, water source, and year, firm,[32] and spatial fixed effects, to begin. Lease clauses are generally defined to be "goods," in that inclusion should benefit the landowner, ceteris paribus. There are several exceptions including: (i) *lease term*, allowing the lessee a longer period of time before having to make the well productive without losing mineral rights; (ii) *sub-surface easement*, allowing firms to lay pipelines and roads as necessary for transporting natural gas from the wellhead; and (iii) *free water*, allowing the operator to use as much water as required without additional cost (with the exception of well water). We then expand our analysis to control for linguistic isolation at the Census tract level and the marginal effect of earning higher incomes on the negotiated lease outcomes.

We begin by describing the relationships between household characteristics that affect

[32]Firm fixed effects control for the company signing each lease in the data, which may not be the company that eventually drills a well.

willingnesses-to-accept in exchange for exposure to drilling disamenities and the characteristics of the leases, reported in Table 4. Increasing household income has a positive impact on the likelihood that leases contain landowner protections, including legal clauses (force majeure, legal fees, pugh clause) and noise restrictions. Higher income lessors also tend to have shorter lease terms (i.e., allowing a shorter period of time before a well must be productive) and fewer free water and sub-surface easement clauses. Related to income, we also control for the reported living area of the household, which may increase a household's willingness-to-pay to avoid exposure to drilling disamenities. We find strong evidence that households living in larger homes are more likely to have landowner protections and higher royalty rates in their leases. In addition to household income and house size, we control for whether the household depends on groundwater, thereby making it more susceptible to water contamination risks, and plot sizes, which may be more valuable to firms in lease negotiations if there are fixed costs in lease bargaining each mineral estate. Results suggest that groundwater houses have fewer "bads" like sub-surface easement and free water clauses in addition to shorter primary term lengths, and landowners are rewarded for leasing larger plots with added protections.

While the characteristics discussed above have a primary interpretation as determinants of willingness-to-pay to avoid externalities from shale gas development, race and ethnicity do not. If willingness-to-pay is indeed not a function of race or ethnicity after controlling for the variables described above, then evidence that it matters for negotiations over lease clauses would suggest inefficient Coasian bargaining. This is, in fact, what we find. In particular, we find that, compared to whites (the excluded race group), Hispanics are likely to have lower royalty rates and longer lease terms (an additional 2.4 months) even after controlling for income. They are also less likely to have legal protections like force majeure, legal fees covered by the firm, and the Pugh clauses (-0.087***)[33] and, separately, vertical Pugh[34] clauses (-0.048***) as reported in the last columns of Table 4b. Moreover, they are less likely to have environmental clauses, clauses limiting surface access, and noise and compression station restrictions. Evaluating the effects of clauses that are less protective of landowners, we find that Hispanic households are more likely to have sub-surface easement clauses (0.042***). There are similar effects observed for Black households, though across fewer lease clause categories, and while Asians tend to have slightly longer lease terms, they largely sign similar leases to white households.

We examine one possible mechanism behind this race effect – asymmetric information. In particular, Hispanic disadvantage may derive from linguistic isolation. Formally, the Census Bureau defines a linguistically isolated household to be one in which no person over the age of 14 speaks English at least very well. In our data, we proxy for this situation with a measure of the percentage of non-English speaking households in the census tract where the household lives, taken from the

[33] Each coefficient can be interpreted as a change in the mean likelihood a lease includes a clause when a household is Hispanic, Black, or Asian. For example, we observe in Table 3 that 29% of leases include a noise restriction, and a Hispanic household is only 21% likely to sign a lease with a noise restriction.

[34] There are two types of Pugh clauses protecting layers of strata vertically (vertical Pugh) or protecting the horizontal acreage. Both of these clauses state that unused minerals stored in strata or acreage revert back to the landowner, which allows the landowner to lease with another firm, potentially, or hold the minerals for other uses.

American Community Survey 2008-2012 data. Specifically, we interact the Hispanic dummy with the fraction of households in that household's Census tract who do not speak English well. A value of 100 would indicate that none of the tract is comprised of English speaking households (guaranteeing that the household in question is linguistically isolated), while a value of 0 would indicate that the entirety of the tract is English speaking (ruling out linguistic isolation). We would expect that linguistic isolation would put a household at a severe disadvantage in lease negotiations, and we test the interacting effect among Hispanic and Asian households. Interestingly, we find that increasing linguistic isolation makes Hispanics significantly more disadvantaged in terms of signing leases containing fewer landowner protections as reported in Table 5. These results speak to a mechanism based on asymmetric information in lease bargaining and points most directly to a breakdown in efficient Coasian bargaining. Conversely, including an interaction between Asian households and being located in a tract with high levels of linguistic isolation suggests the opposite – that Asians sign worse leases, on average, and linguistic isolation improves their negotiation outcomes, which is somewhat counter-intuitive. The final model variation reported in Table 6 estimates the models that include interactions between race and ethnicity and the household measures of income. Higher income may allow the household to retain the services of an attorney to assist in the lease negotiations, offsetting any informational disadvantage. Among Hispanics, patterns from the prior specifications persist, and controlling for their household income increases the likelihood that they sign a lease with the specified landowner protection. Similarly, Black households with higher income are more likely to sign leases with environmental (0.469*) and surface restoration (0.362**) clauses. Asian households with higher incomes are also more likely to have better lease outcomes as they sign leases with fewer "bads" like sub-surface easement (-0.846*) and free water (-0.937**) clauses. Further, the effect of being an Asian household disappears contrary to what we observed in Table 5; however, Asian households located in tracts with low levels of English speaking households still are more likely to sign leases with landowner protections.

Turning to the covariance matrix describing the residuals from the SUR procedure (Table 7), note that all of the larger values are positive and the negative values are concentrated in the rows and columns for clauses that are less protective of landowners like sub-surface easement, free water, and primary term length. This indicates a role for idiosyncratic bargaining ability – i.e., aside from race, income and other observable characteristics, an individual who negotiates for one good clause is likely to negotiate for other good clauses as well, including a higher royalty rate and shorter primary term lengths.

6.2 Violations

In the above analysis, we find that lease quality is not distributed evenly across the population in our data, and we find that race and ethnicity explain some of this variation, even after controlling for income, suggesting environmental injustice. However, inequitable distribution only matters if we find that legal restrictions stipulated in the leasing document effectively deters bad drilling behavior that leads to negative externalities born by households located near to drilling activity. We build suggestive evidence that lease contents may matter for future drilling behavior by estimating Census tract level regressions relating the prevalence of landowner protections to future violations.

Each estimate and standard deviation in Table 8 represents a separate regression that captures the effect of average level lease protections on the incidence of future violations. In particular, for each Census tract, we calculate the monthly, cumulative mean incidence of a particular landowner protection. Similarly, we match our aggregate lease quality measures to cumulative violations (by month) occurring after the leases are signed. We find that higher frequencies of landowner protections are negatively related to future violations as indicated by the negative and statistically significant estimates (required fences are an exception discussed in the following paragraph). Our results are consistent across different measures of landowner protections (rows) and violation types (columns), which include landowner complaints and air and waste violations measured by tract (first four columns) and violations per well by tract (last four columns).

Included in the list of potential landowner protections are fences, which requires a physical barrier be built around the well site. In contrast to the other landowner protections like legal restrictions, environmental, and noise clauses, fences appear ineffective at mitigating future negative drilling disamenities.

6.3 Ordinances

As discussed in the introduction, Texas had (until recently) allowed municipalities to exercise "home rule", passing local ordinances that restrict drilling behavior in ways similar to landowner protections found in the leasing agreements. This sub-section describes the relationship between household characteristics and types of regulations passed in their municipalities at the time they sign leases, which is reported in Table 10, the likelihood an ordinance is passed as a function of average lease quality at the municipality level, reported in Table 10, and the relationship between ordinances passed and future violations, reported in Table 11.

Beginning with the estimates reported in the first column of Table 10, we find that ordinances are more likely to have passed in areas where leases signed have smaller land areas (-0.03***), that are located nearer to drilling activity (0.017***), and where leases are signed by black (0.144**) and Hispanic (0.118***) households. These results most likely follow from black and Hispanic households living in more densely populated areas of Tarrant County like Fort Worth and Arlington, both areas governed by more extensive municipal ordinances. Comparing estimates across columns, we find that black and Hispanic households are protected from some water contamination risks through saltwater and pit restrictions, and from disturbances through restrictive noise ordinances and working (fracturing) hours.

Table 10 reports estimates that capture the likelihood an ordinance is passed as a function of cumulative mean lease quality across leases signed in that city. We present these results to suggest that there may be substitution between ordinances and lease quality in our data, and we find that areas with lower incidences of landowner protections pass ordinances less often as evidenced by the negative and significant survival estimates.

Finally, we test whether ordinances are a deterrent to bad drilling behavior, paralleling the analysis presented in Table 8. Table 11 reports estimates for each model relating the passage of a particular ordinance to cumulative future violation frequency by Census tract. Similar to landowner protections written into leases, we find that ordinances deter poor drilling practices, reducing complaints of air and waste violations by tract (first four columns) and per well by tract (last four columns). We only estimate the effect of noise and hour restrictions on complaints since these ordinances are unlikely to mitigate air and waste violations.

Based on our empirics, we find that Hispanic and black households are likely located in areas that had been protected by municipal ordinances that deterred poor drilling behavior, similarly to the deterrent effects of more stringent landowner protections in leases. Further, we find evidence that ordinances substitute for landowner protections in these areas. However, House Bill 40 passed in Texas (along with legal disputes that have arisen in other states) limit the jurisdiction of local ordinances when they conflict with commercial mineral development approved by the states. Based on our results, these legal limitations negatively affect minority households who, in the absence of ordinances, are also less likely to be protected through negotiated lease terms.

7 Conclusions

We undertake an analysis of the determinants of the characteristics of leases negotiated as part of the bargaining process for the assignment of rights to develop shale gas resources. With the dramatic growth in U.S. shale gas development over the last decade (particularly in populated areas), lease negotiations have become an important part of the energy landscape, and constitute one of the primary potential sources of benefit for homeowners. This is significant, as there are also many potential drawbacks to living near a shale gas well. The bargaining process associated with the transfer of mineral rights from lessor to lessee shares many features of a classic Coasian bargaining framework. If bargaining is, in fact, Coasian, that would suggest an efficiency result that would reduce the need for costly government oversight of the leasing process. Using a unique combination of data sets, we test for whether the bargaining process does indeed exhibit characteristics of Coasian efficiency in one of the most active shale gas counties in the U.S. - Tarrant Co., Texas. Our results suggest that income, an important determinant of willingness-to-accept payment in exchange for experiencing the nuisances associated with shale gas development, does indeed affect bargaining outcomes. This result is indicative of Coasian efficiency - those who we would expect to have a larger willingness-to-accept indeed negotiate for stronger lease terms. However, the story does not end there. The argument in favor of Coasian efficiency becomes harder to sustain when we find similar results for race and ethnicity. Conditioning upon income, there is no reason to expect different racial and ethnic groups to have a different willingness-to-accept to avoid environmental harm, so the fact that we find significant differences in lease quality across race groups suggests a realization of environmental injustice.

The question then arises as to what enables that injustice. One possibility would be the leverage that operators can exert in lease negotiations due to forced pooling. **CITE JMP** A second possibility is that it is the result of information asymmetry. There are lots of potential sources of information asymmetry that one could think of in the lease bargaining process, but the simplest (which is also most relevant for the most disadvantaged minority group) would likely be linguistic – i.e., a household will have less ability to bargain effectively if it is not English speaking. Our results suggest that this is indeed a source of the outcome experienced by the Hispanic group in the bargaining process. Asymmetric information presents a clear mechanism for the breakdown of efficient Coasian bargaining.

Moving forward, there are several alternative paths for communities tasked with negotiating leases because of new natural gas discoveries. Access to information about lease negotiation is increasingly available that details the potential terms and implications. Usually, these are documents drawn by attorneys that represent property owners, and reading this information decreases the asymmetry in information between property owners and firms that are likely seasoned negotiators.

More broadly, states could adopt uniform leasing requirements whereby leases are required to have a minimum set of terms deemed fair to households relinquishing the rights to their subsurface minerals for natural gas extraction. Establishing a minimum requirement ensures that all households are protected up to a minimum threshold established by the regulating body that could be based on the experience of communities with currently active natural gas industries.

Uniform leasing is not yet observed in practice. However, stricter regulations overseeing the natural gas industry and their treatment of surface and subsurface estates during and after production can substitute for it. Until recently, local municipalities in the state of Texas were allowed to exercise "home rule", which means they could pass stricter rules governing firms operating within their jurisdictions. These rules were more or less strict across cities, with some requiring additional environmental testing, remediation and protection of the landscape, local permitting standards, and restricting noise and the hours of operation. These rules had provided a backstop for vulnerable populations who were unable to bargain effectively for protections in private lease negotiations. With the passage of HB40 in Texas and other similar measures in other parts of the country, understanding the ways in which the lease bargaining process may not live up to the Coasian ideal becomes all the more important.

Table 1: Well Exposure (Within 2000 Meters)

Panel (a): Well count within 2000 meters

	Mean	N[a]	Std. Dev.
2003	0.24	726049	1.22
2004	0.38	724328	1.48
2005	0.56	721845	1.71
2006	0.81	718515	2.00
2007	1.03	716709	2.20
2008	1.24	713039	2.35
2009	1.40	710400	2.40
2010	1.65	709020	2.47
2011	1.96	706499	2.55
2012	2.15	704173	2.56
2013	2.20	702881	2.57

Panel (b): Minimum distance

	Mean	N	Std. Dev.
2003	10436.8	727668	5211.23
2004	9712.2	727668	5509.89
2005	7260.14	727668	5038.53
2006	5404.38	727668	4196.38
2007	3848.77	727668	3060.07
2008	2833.07	727668	2090.44
2009	2494.68	727668	1781.34
2010	2057.97	727668	1519.14
2011	1620.81	727668	1235.65
2012	1354.99	727668	971.21
2013	1311.81	727668	947.8

[a] The large sample sizes reflect observing the well exposure for each property in the data for each month and year spanning Jan. 2003 to Dec. 2013.

Table 2: Summary Statistics

	Obs.	Mean	St.Dev.	Min.	Max.
		(a) Household Summary			
Land size (sqft)	9241	10138.12	6389.08	4400	74139
Living area (sqft)	9241	2100.87	834.75	485	7950
Income (1e3)	9241	81.03	74.13	4	2111
Groundwater	9241	0.69	0.46	0	1
Hispanic	9241	0.22	0.41	0	1
Black	9241	0.11	0.32	0	1
Asian	9241	0.05	0.21	0	1
White	9241	0.82	0.38	0	1
No English (Pct.)	9122	10.32	8.72	0	52
		(b) Violation Summary (Census Tract)			
Total	105	4.2	5.67	1	23
Complaint	105	3.86	5.77	0	23
Air	105	4.04	5.77	0	23
Waste	105	0.15	0.43	0	2
Producing Well Count	1707	66.16	144.1	1	861
		(c) Ordinance Summary (City)			
Air Restriction	33	0.1	0.21	0	1
Water Restriction	33	0.16	0.21	0	1
Pit Restriction	33	0.29	0.28	0	1
Saltwater Restriction	33	0.45	0.19	0	1
Noise	33	0.46	0.25	0	1
Fracturing Hours	33	0.59	0.39	0	1
Work Hours	33	0.14	0.04	0	0

Notes: (i) The top panel describes the individual household observations used to estimate the Coasian SURs; (ii) the middle panel describes the tract-level data used to relate violation outcomes to leasing agreements signed in a given census tract; (iii) the lower panel summarizes local ordinance strength across cities in Tarrant County where the ordinance values are bound by zero and one; (iv) the ordinance summary describes the probability an ordnance has been passed for a given Census Tract and month.

Table 3: Lease Quality Summary Statistics

	Full Lease Sample			Coase Sample		
Clause	Obs.	Mean	St.Dev.	Obs.	Mean	St.Dev.
Royalty	176379	0.231	0.024	8969	0.242	0.018
Term Length (months)	284798	42.466	11.886	9164	42.737	11.49
Dis-amenity Bundle		0.161	0.238		0.159	0.242
Environmental		0.316	0.465		0.306	0.461
Noise		0.293	0.455		0.281	0.45
Freshwater Protect		0.022	0.146		0.029	0.168
Surface Casing		0.008	0.091		0.01	0.101
Compression Station		0.004	0.065		0.009	0.093
Legal Bundle		0.225	0.22		0.226	0.219
Force Majuere		0.513	0.5		0.513	0.5
Pugh		0.399	0.49		0.386	0.487
Offset Well		0.129	0.335		0.151	0.358
Insurance/Indemnity		0.074	0.262		0.067	0.251
Reporting		0.012	0.109		0.015	0.12
No Top Lease		0.079	0.27		0.078	0.268
Surface Bundle		0.556	0.231		0.546	0.243
No Surface Access		0.778	0.416		0.765	0.424
Surface Restriction		0.106	0.308		0.118	0.323
Surface Damage		0.785	0.411		0.756	0.429
"Bads" Bundle		0.217	0.182		0.218	0.178
Sub-surface Easement		0.613	0.487		0.62	0.485
Injection Well		0.021	0.143		0.024	0.152
Free Water Access		0.017	0.129		0.011	0.102
Clause Obs.	75731			9241		

Notes: (i) The two sets of columns compare the lease attributes across the full set of leases for which we have data and the sub-sample used to estimate the Coasian SURs; (ii) the *Bundles* are comprised of the sets of binary clauses listed beneath the bundle headings; (iii) each observation has a one for each clause written into the lease.

Table 4: Coase Seemingly Unrelated Regressions

	Royalty	Term Length	Env.	Noise	Surface Damage	Free water
			(a) Part I			
Asian	0.002	1.216**	-0.026	-0.009	-0.001	-0.008
	(0.002)	(0.510)	(0.019)	(0.019)	(0.018)	(0.020)
Black	0.001	1.610***	-0.083***	-0.061***	-0.016	-0.002
	(0.001)	(0.352)	(0.013)	(0.013)	(0.012)	(0.014)
Hispanic	-0.003***	2.401***	-0.079***	-0.072***	0.026***	0.018
	(0.001)	(0.281)	(0.011)	(0.011)	(0.010)	(0.011)
Income	0.002	-5.574***	0.101	0.224***	0.047	-0.139**
	(0.006)	(1.663)	(0.063)	(0.062)	(0.058)	(0.067)
Groundwater	-0.006*	-2.616***	-0.015	0.009	-0.082***	-0.098***
	(0.003)	(0.884)	(0.034)	(0.033)	(0.031)	(0.035)
Living area (in sqft)	0.002***	-1.144***	0.025***	0.021***	-0.001	-0.019***
	(0.001)	(0.167)	(0.006)	(0.006)	(0.006)	(0.007)
Land area (in sqft)	0.000***	0.014	0.001	0.002**	0.000	0.001
	(0.000)	(0.023)	(0.001)	(0.001)	(0.001)	(0.001)
R-squared	0.192	0.282	0.421	0.356	0.378	0.395

	Compress. Station	Surface Rest.	Subsurf. Easement	No Top Lease	Legal Bundle	Vertical Pugh
			(b) Part II			
Asian	-0.005	-0.030**	-0.016	-0.019	-0.020	0.007
	(0.004)	(0.013)	(0.019)	(0.012)	(0.020)	(0.017)
Black	-0.000	-0.040***	0.066***	-0.035***	-0.073***	-0.074***
	(0.003)	(0.009)	(0.013)	(0.008)	(0.013)	(0.012)
Hispanic	-0.011***	-0.057***	0.042***	-0.044***	-0.087***	-0.048***
	(0.002)	(0.007)	(0.010)	(0.007)	(0.011)	(0.009)
Income	0.004	-0.001	-0.158**	0.052	0.166***	0.065
	(0.013)	(0.043)	(0.062)	(0.039)	(0.064)	(0.055)
Groundwater	-0.012*	0.007	-0.160***	-0.108***	0.017	-0.008
	(0.007)	(0.023)	(0.033)	(0.021)	(0.034)	(0.029)
Living area (in sqft)	-0.004***	0.045***	-0.001	0.037***	0.033***	0.008
	(0.001)	(0.004)	(0.006)	(0.004)	(0.006)	(0.006)
Land area (in sqft)	-0.001***	0.002***	0.001	0.004***	0.003***	0.004***
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R-squared	0.335	0.401	0.446	0.275	0.411	0.337
Observations	8,582	8,582	8,582	8,582	8,582	8,582
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: (i) Each column represents a separate regression of lease clause types on the observable attributes of households in the data; (ii) *Term Length* and *Subsurface Easement* are considered clauses that are less protective of landowners, so a positive coefficient suggests the household is worse off; (iii) the reported specifications are robust to estimation with wellpad fixed effects.

Table 5: Coase Seemingly Unrelated Regressions with Linguistics Interactions

	Royalty	Term Length	Env.	Noise	Surface Damage	Free water
			(a) Part I			
Asian	0.002	1.406*	-0.136***	-0.113***	0.001	-0.044
	(0.003)	(0.853)	(0.033)	(0.032)	(0.030)	(0.034)
Black	0.001	1.273***	-0.077***	-0.051***	-0.013	-0.003
	(0.001)	(0.354)	(0.013)	(0.013)	(0.012)	(0.014)
Hispanic	0.004**	1.316***	-0.021	-0.020	0.006	-0.017
	(0.002)	(0.462)	(0.018)	(0.017)	(0.016)	(0.018)
Income	0.000	-5.484***	0.121*	0.253***	0.032	-0.158**
	(0.006)	(1.669)	(0.064)	(0.062)	(0.059)	(0.067)
No English	-0.000***	0.086***	0.002**	0.001	-0.003***	-0.003***
	(0.000)	(0.020)	(0.001)	(0.001)	(0.001)	(0.001)
Asian*No English	-0.000	-0.037	0.010***	0.010***	0.000	0.003
	(0.000)	(0.061)	(0.002)	(0.002)	(0.002)	(0.002)
Hispanic*No English	-0.000***	0.030	-0.004***	-0.003***	0.002**	0.003***
	(0.000)	(0.028)	(0.001)	(0.001)	(0.001)	(0.001)
R-squared	0.200	0.294	0.424	0.368	0.378	0.406
	Compress. Station	Surface Rest.	Subsurf. Easement	No Top Lease	Legal Bundle	Vertical Pugh
			(b) Part II			
Asian	0.004	-0.048**	0.028	-0.047**	-0.125***	-0.105***
	(0.007)	(0.021)	(0.031)	(0.020)	(0.032)	(0.028)
Black	-0.002	-0.023***	0.061***	-0.026***	-0.066***	-0.063***
	(0.003)	(0.009)	(0.013)	(0.008)	(0.013)	(0.011)
Hispanic	0.007*	-0.044***	0.016	-0.032***	-0.017	-0.015
	(0.004)	(0.011)	(0.017)	(0.011)	(0.018)	(0.015)
Income	0.008	-0.002	-0.186***	0.036	0.198***	0.088
	(0.013)	(0.041)	(0.061)	(0.039)	(0.063)	(0.054)
No English	0.001***	-0.005***	-0.003***	-0.004***	0.002***	-0.000
	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)
Asian*No English	-0.001**	0.003*	-0.004*	0.003**	0.009***	0.010***
	(0.000)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
Hispanic*No English	-0.001***	0.001**	0.002*	0.001	-0.004***	-0.001
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R-squared	0.333	0.428	0.466	0.287	0.424	0.360
Observations	8,582	8,582	8,582	8,582	8,582	8,582
City, Period, Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: (i) Each column represents a separate regression of lease clause types on the observable attributes of households in the data; (ii) *Term Length* and *Subsurface Easement* are considered clauses that are less protective of landowners, so a positive coefficient suggests the household is worse off; (iii) the reported specifications are robust to estimation with wellpad fixed effects; (iv) the *Other Controls* include the land size (in sqft.), living area (in sqft.), and a dummy for houses accessing groundwater; (v) the interactions with *No English* represent the fraction of households located in a Census Tract who do not speak English well.

Table 6: Coase Seemingly Unrelated Regressions with Linguistics & Income Interactions

(a) Part I

	Royalty	Term Length	Env.	Noise	Surface Damage	Free water
Asian	0.005	0.504	-0.097**	-0.133***	-0.007	0.045
	(0.004)	(1.280)	(0.049)	(0.047)	(0.045)	(0.051)
Black	0.000	0.976	-0.109***	-0.060***	0.012	0.009
	(0.002)	(0.617)	(0.024)	(0.023)	(0.022)	(0.024)
Hispanic	0.005**	3.040***	-0.024	-0.023	0.086***	0.035
	(0.002)	(0.700)	(0.027)	(0.026)	(0.025)	(0.027)
Income	0.001	-4.998***	0.108	0.243***	0.084	-0.104
	(0.006)	(1.730)	(0.066)	(0.064)	(0.061)	(0.070)
No English	-0.000***	0.090***	0.002**	0.001	-0.003***	-0.003***
	(0.000)	(0.021)	(0.001)	(0.001)	(0.001)	(0.001)
Asian*No English	-0.000	-0.023	0.009***	0.010***	0.000	0.002
	(0.000)	(0.064)	(0.002)	(0.002)	(0.002)	(0.003)
Hispanic*No English	-0.000***	0.004	-0.004***	-0.003***	0.001	0.002*
	(0.000)	(0.029)	(0.001)	(0.001)	(0.001)	(0.001)
Asian*Income	-0.028	9.913	-0.408	0.215	0.092	-0.937**
	(0.035)	(10.181)	(0.388)	(0.377)	(0.358)	(0.398)
Black*Income	0.013	4.301	0.469*	0.126	-0.366	-0.172
	(0.025)	(7.264)	(0.277)	(0.269)	(0.255)	(0.283)
Hispanic*Income	-0.011	-25.575***	0.047	0.039	-1.169***	-0.746**
	(0.027)	(7.732)	(0.295)	(0.286)	(0.272)	(0.303)
R-squared	0.201	0.295	0.425	0.368	0.379	0.406

(b) Part II

	Compress. Station	Surface Rest.	Subsurf. Easement	No Top Lease	Legal Bundle	Vertical Pugh
Asian	0.005	-0.054*	0.109**	-0.057*	-0.117**	-0.128***
	(0.010)	(0.032)	(0.047)	(0.030)	(0.049)	(0.042)
Black	0.002	-0.049***	0.035	-0.033**	-0.070***	-0.070***
	(0.005)	(0.015)	(0.023)	(0.015)	(0.023)	(0.020)
Hispanic	0.007	-0.096***	0.077***	-0.062***	-0.024	-0.054**
	(0.005)	(0.017)	(0.026)	(0.017)	(0.027)	(0.023)
Income	0.012	-0.043	-0.155**	0.015	0.194***	0.061
	(0.013)	(0.043)	(0.063)	(0.041)	(0.066)	(0.056)
No English	0.001***	-0.005***	-0.002***	-0.005***	0.002***	-0.000
	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)
Asian*No English	-0.001*	0.003*	-0.006**	0.003**	0.009***	0.011***
	(0.000)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Hispanic*No English	-0.001***	0.002***	0.001	0.001	-0.004***	-0.001
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Asian*Income	-0.021	0.064	-0.846**	0.109	-0.087	0.240
	(0.079)	(0.252)	(0.373)	(0.240)	(0.387)	(0.331)
Black*Income	-0.065	0.362**	0.380	0.099	0.048	0.095
	(0.056)	(0.180)	(0.266)	(0.171)	(0.276)	(0.236)
Hispanic*Income	-0.004	0.771***	-0.890***	0.445**	0.107	0.559**
	(0.060)	(0.192)	(0.283)	(0.182)	(0.294)	(0.251)
R-squared	0.333	0.429	0.467	0.288	0.424	0.360
Observations	8,582	8,582	8,582	8,582	8,582	8,582
City, Period, Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: (i) Each column represents a separate regression of lease clause types on the observable attributes of households in the data; (ii) *Term Length* and *Subsurface Easement* are considered clauses that are less protective of landowners, so a positive coefficient suggests the household is worse off; (iii) the reported specifications are robust to estimation with wellpad fixed effects; (iv) the *Other Controls* include the land size (in sqft.), living area (in sqft.), and a dummy for houses accessing groundwater.

Table 7: SUR Correlation Matrix

	Royalty	Term Length	Env.	Noise	Surface Damage	Free Water
Royalty	1					
Term Length (months)	-0.2825	1				
Environmental	0.1667	-0.3038	1			
Noise	0.1509	-0.3185	0.6278	1		
Surface Damage	0.0503	0.0008	0.0898	0.0021	1	
Free Water Access	-0.0733	0.2774	-0.3648	-0.4434	0.2407	1
Compression Station	0.0038	0.0483	0.1559	0.1559	-0.1295	-0.0323
Surface Restriction	0.0277	-0.1599	0.3143	0.3969	-0.1823	-0.2002
Sub-surface Easement	-0.1118	0.326	-0.4391	-0.6582	0.0983	0.5282
No Top Lease	0.0361	-0.1199	0.3006	0.3846	-0.2129	-0.1588
Legal Bundle	0.1686	-0.3285	0.6568	0.8385	-0.0915	-0.4576
Pugh	0.1114	-0.2405	0.4828	0.6475	-0.0501	-0.3674

	Compression Station	Surface Rest.	Sub-surf. Easement	No Top Lease	Legal Bundle
Compression Station	1				
Surface Restriction	0.1346	1			
Sub-surface Easement	-0.0532	-0.3072	1		
No Top Lease	0.1924	0.748	-0.2778	1	
Legal Bundle	0.152	0.3471	-0.5512	0.3301	1
Pugh	0.1447	0.3756	-0.5737	0.3186	0.5885

Notes: (i) The correlation matrix is based on the SUR estimates reported in Table 5 that includes linguistic interactions among the dependent variables; (ii) the table reports the correlations of residuals across the set of lease clause equations.

Table 8: Tract Level Violation Regressions

	Violations After Signing				Violations per Producing Well			
	Total	Complaint	Air	Waste	Total	Complaint	Air	Waste
Legal bundle	-0.181**	-0.177**	-0.173**	-0.012	-0.158***	-0.053	-0.054	-0.091***
	(0.072)	(0.070)	(0.072)	(0.008)	(0.043)	(0.040)	(0.040)	(0.017)
Surface clause bundle	-0.382***	-0.334***	-0.355***	-0.024***	-0.233***	-0.152***	-0.152***	-0.070***
	(0.032)	(0.031)	(0.032)	(0.004)	(0.023)	(0.021)	(0.021)	(0.009)
Externality bundle	-0.497***	-0.474***	-0.492***	-0.015*	-0.118***	-0.069*	-0.069*	-0.043***
	(0.076)	(0.074)	(0.076)	(0.008)	(0.040)	(0.038)	(0.038)	(0.015)
Full set of clauses	-0.379***	-0.342***	-0.359***	-0.022***	-0.180***	-0.099***	-0.099***	-0.071***
	(0.053)	(0.051)	(0.053)	(0.006)	(0.032)	(0.030)	(0.030)	(0.012)
Environmental clause	-0.100***	-0.103***	-0.102***	0.007*	-0.012	0.017	0.017	-0.025***
	(0.035)	(0.034)	(0.035)	(0.004)	(0.019)	(0.018)	(0.018)	(0.007)
Noise Restriction	-0.402***	-0.361***	-0.385***	-0.024***	-0.081***	-0.056***	-0.056***	-0.023***
	(0.042)	(0.041)	(0.042)	(0.005)	(0.022)	(0.020)	(0.020)	(0.008)
Fence	0.462***	0.168**	0.357***	0.112***	0.598***	0.657***	0.657***	-0.054**
	(0.078)	(0.075)	(0.077)	(0.009)	(0.065)	(0.061)	(0.061)	(0.025)

Notes: (i) Each estimate and standard error represents a separate regression of violations on the tract level rate of lease clauses by tract; (ii) lease clause measures are the cumulative mean of clauses written into contracts in a tract; (iii) violations are measured as the sum occurring after the leases are signed.

Table 9: Ordinance & Household Characteristic Correlations

	Air	Soil	Water	Flood	Noise	Fracture Hours	Work Hours	Pit	Saltwater
Groundwater	0.218	0.256	0.108	0.335	0.193	-0.034	0.208	0.316	0.474
Living Area	0.494	0.136	0.358	0.057	0.344	0.011	0.221	0.069	0.195
Land Area	0.281	0.019	0.153	-0.209	-0.262	-0.238	-0.551	-0.086	-0.304
Asian	0.374	0.243	0.387	0.594	0.353	-0.014	0.115	0.289	0.468
Black	0.072	-0.311	-0.064	0.449	0.255	0.070	-0.035	-0.014	0.383
Hispanic	-0.236	-0.201	-0.282	0.154	-0.283	0.241	0.179	-0.265	0.252
White, Hispanic	-0.234	-0.187	-0.297	0.137	-0.304	0.249	0.192	-0.263	0.250
White, Non-Hispanic	0.110	0.225	0.191	-0.361	0.099	-0.220	-0.152	0.175	-0.403
Income	0.351	0.308	0.261	-0.063	0.320	-0.004	0.287	0.021	0.026
Drilling Exp.	-0.271	-0.194	-0.311	0.294	0.209	-0.094	0.177	-0.353	-0.064
Observations	34								

Notes: (i) Correlations between the average household characteristic in a given city and the stringency of regulation passed by regulation category; (ii) Asian and high income households are more likely to be located in areas with more stringent regulations while Hispanic and black households live in areas with fewer protections.

Table 10: Ordinance & Lease Characteristic Correlations

	Environ.	Noise	Surf. Damage	Free water	Compression Station
Air restriction	-0.021	-0.062	0.048	-0.141	-0.035
Soil restriction	0.156	0.078	0.26	-0.146	0.057
Water restriction	0.049	0.025	0.265	-0.253	0.107
Flood restriction	0.279	0.263	0.14	0.044	0.069
Noise	0.425	0.241	0.534	0.292	0.402
Fracturing Hours	-0.057	0.062	-0.009	-0.131	-0.166
Working Hours	0.122	0.127	0.151	0.188	0.145
Pit Restriction	0.22	0.149	0.372	0.109	0.055
Saltwater Restriction	0.222	0.178	-0.229	0.086	0.086
	No Surface Access	Sub-surface easement	Top lease	Legal Bundle	Vertical Pugh
Air restriction	0.076	0.072	-0.169	0.04	-0.006
Soil restriction	0.354	0.171	-0.132	0.265	0.298
Water restriction	0.268	0.245	0.073	0.116	0.145
Flood restriction	0.249	0.021	0.071	0.26	0.289
Noise	0.53	0.376	0.042	0.452	0.45
Fracturing Hours	-0.162	-0.304	0.048	0.026	-0.012
Working Hours	0.067	0.274	0.173	0.038	0.083
Pit Restriction	0.331	0.201	0.213	-0.028	0.052
Saltwater Restriction	0.025	-0.245	-0.014	0.415	0.32
Observations	34				

Notes: (i) Correlations between the average lease quality in a city at the time an ordinance is passed and the stringency of the passed ordinance; (ii) suggests some substitution and complementarity between lease quality and ordinance type; (iii) Tables and together suggest that minorities may live in cities where ordinances are passed, but more stringent ordinances are likely in areas with higher income and fewer minorities.

Table 11: Tract Level Ordinance Regressions

	Violations After Signing				Violations per Producing Well			
	Total	Complaint	Air	Waste	Total	Complaint	Air	Waste
Ordinance Dum.	0.005	-0.004	-0.001	0.004*	-0.012	-0.027***	-0.027***	0.017***
	(0.018)	(0.018)	(0.018)	(0.002)	(0.009)	(0.009)	(0.009)	(0.003)
Air Restriction	-0.599***	-0.567***	-0.599***	0.006	-0.148**	-0.113*	-0.113*	-0.034
	(0.135)	(0.131)	(0.134)	(0.015)	(0.073)	(0.068)	(0.068)	(0.028)
Water Restriction	-1.183***	-1.087***	-1.154***	-0.043***	-0.418***	-0.305***	-0.305***	-0.108***
	(0.076)	(0.074)	(0.076)	(0.008)	(0.040)	(0.037)	(0.037)	(0.015)
Pit Restriction	-0.109**	-0.051	-0.083	-0.021***	-0.182***	-0.138***	-0.138***	-0.042***
	(0.054)	(0.052)	(0.053)	(0.006)	(0.033)	(0.030)	(0.030)	(0.012)
Saltwater Restriction	0.009	-0.010	-0.003	0.008**	-0.020	-0.048***	-0.048***	0.031***
	(0.036)	(0.035)	(0.036)	(0.004)	(0.018)	(0.016)	(0.016)	(0.007)
Noise	0.089***	0.075***			-0.022*	-0.021*		
	(0.025)	(0.024)			(0.012)	(0.012)		
Fracturing Hours	-0.207***	-0.211***			-0.041***	-0.058***		
	(0.026)	(0.026)			(0.012)	(0.012)		
Work Hours	-0.524***	-0.512***			-0.261***	-0.312***		
	(0.120)	(0.116)			(0.057)	(0.053)		

Notes: (i) Each estimate and standard error represents a separate regression of violations on the tract level rate of ordinance types that have passed at the municipal level by tract; (ii) violations are measured as the sum occurring after the leases are signed.

Table 12: Split Estates (Census tract level)

(a) Violations

	Total	Complaint	Air	Waste
Split Estate (Avg.)	0.005*	0.006*	0.006**	0.003
	(0.003)	(0.003)	(0.003)	(0.014)
Observations	214	214	214	214
R-squared	0.018	0.017	0.019	0.000

(b) Lease Quality

	Royalty	Surface Bundle	Freshwater	No Surf. Access	Attorney Fee	Free water
Split Estate (Avg.)	0.282***	-0.132**	0.319***	-0.117***	0.193*	-0.056*
	(0.091)	(0.062)	(0.080)	(0.039)	(0.101)	(0.029)
Observations	214	214	214	214	214	214

Notes: (i) Each estimate and standard error in 12a represents a separate regression of total Census tract level violations on the mean levels of split estates by Census tract; (ii) estimates in 12b represent separate regressions of mean Census tract level lease quality on the mean levels of split estates for select lease clause types.

Table 13: Race/Ethnicity and Well Exposure Regressions

	(1)	(2)	(3)	(4)	(5)	(6)
Hispanic	-0.009	-0.354***	-0.104**	-0.385***	0.048	-0.013
	(0.045)	(0.041)	(0.047)	(0.041)	(0.036)	(0.038)
Black	0.759***	0.573***	0.698***	0.554***	0.905***	0.887***
	(0.057)	(0.048)	(0.057)	(0.048)	(0.045)	(0.045)
HH Income			-2.199***	-0.911***	-0.903***	-0.688***
			(0.272)	(0.134)	(0.139)	(0.125)
Groundwater					9.350***	9.375***
					(0.115)	(0.115)
Land area (in sqft)					41.595***	45.018***
					(2.856)	(2.858)
Appraisal Value (log)						-0.222***
						(0.031)
Observations	98,202	98,202	98,202	98,202	98,202	98,202
R-squared	0.002	0.290	0.003	0.291	0.458	0.459
City FE	No	Yes	No	Yes	Yes	Yes
Period FE	No	Yes	No	Yes	Yes	Yes

Table 14: Race/Ethnicity and Bonus Regressions

	(1)	(2)	(3)	(4)
Hispanic	-1,891.114***	-3,802.096***	-1,705.472***	-3,643.880***
	(560.627)	(698.819)	(557.844)	(695.806)
Black	-282.351	-2,770.889***	-132.283	-2,571.420***
	(528.568)	(813.404)	(545.618)	(823.622)
Hispanic*Split			1,264.568	3,820.353
			(2,424.327)	(3,607.463)
HH Income	4,910.478***	9,377.261***	6,463.129***	11,113.282***
	(1,650.424)	(2,169.154)	(1,726.807)	(2,271.149)
Income*Split			223.810	2,679.094
			(4,376.411)	(5,391.388)
Land area (in sqft)	86.640***	230.932***	100.425***	244.440***
	(31.812)	(40.115)	(32.025)	(40.170)
Groundwater	-505.375	-3,697.928**	-2,191.796	-5,248.621**
	(648.274)	(1,845.165)	(1,961.589)	(2,188.336)
Observations	686	686	730	730
R-squared	0.747	0.519	0.735	0.500
City FE	Yes	Yes	Yes	Yes
Period FE	Yes	Yes	Yes	Yes
Firm FE	Yes	No	Yes	No

Table 15: Race/Ethnicity Correlations with Income and Linguistic Isolation

	Income	Speaks English Poorly		Linguistic Isolation	
	(1)	(2)	(3)	(4)	(5)
Hispanic	-36,469.221***	2.080***	1.990***	1.848***	1.768***
	(1,611.818)	(0.060)	(0.061)	(0.055)	(0.057)
Black	-31,893.472***	-0.197	-0.327*	-0.174	-0.311**
	(1,985.385)	(0.187)	(0.187)	(0.155)	(0.157)
Other	-35,915.070**	1.023**	1.103**	1.518***	1.574***
	(16,353.763)	(0.463)	(0.458)	(0.332)	(0.327)
HH Income		-0.000***	-0.000***	-0.000***	-0.000***
		(0.000)	(0.000)	(0.000)	(0.000)
Observations	23,352	23,352	23,352	23,352	23,352
Adjusted R2	0.029	0.436	0.446	0.408	0.414
PUMA FE	No	No	Yes	No	Yes

A Appendix: Data Description

A.1 Scraping and Text-mining Lease Data

The auxiliary clauses are obtained by scraping the leasing documents from the "Drilling Down" series (**?**) published by the *New York Times* or the Tarrant County Clerk office website. Each scraped document is converted from pdf image files to text documents and text-mined for specific language indicating the existence of different clauses negotiated into the contracts. The sample with auxiliary clauses in the analysis is roughly 90,000 observations.

The pdf image documents are converted to text documents using a combination of OCR (optical character recognition) software Tesseract.[35] Following conversion, I use a list of regular expression patterns indicating inclusion of each clause to search and identify leases containing those clauses with software written in Python. The use of regular expression functions allows one to search for fragments of words while also accounting for misspellings and superfluous punctuation that might prevent a perfect match between phrases. Perfect matches are particularly difficult to locate in converted text documents especially when the original copy is a pdf image, and often conversion results in misplaced spaces, characters, numbers, and letters. Below are examples of the regular expression patterns used to search for surface damage and restricted surface access clauses.

1. No Surface Use:
   (a) "No surface use"
   ```
   r‘[rmn][ao0][\s+]*su[rmn]f[ao0][\w+]*[\s+]*use’,
   ```
   (b) "No surface operations":
   ```
   r‘[rmn][ao0][\s+]*[\w+]*[\s+]*[\\\~>/!\%\_,.-‘"\’()\$?@\#\d:;]*
    [\s+]*su[rmn]f[ao0][\w+]*[\s+]*[ao0]pe[rmn][ao0]t\w+’
   ```
   (c) "Lessee shall not conduct any surface operations"
   ```
   r‘[l1]es[s]*[\w+]*[\s+]*sh[ao0][l1][l1]*[\s+]*[rmn][ao0]t[\s+]*
    c[ao0][rmn]d\\w+[\s+]*[\w+]*[\s+]*[\\\~>/!\%\_,.-‘"\’()\$?@\#\\d:;]*
    [\s+]*su[rmn]f[ao0][\w+]*[\s+]*[ao0]pe[rmn][ao0]t\w+’
   ```
   (d) "Lessee shall not enter upon w surface"
   ```
   r‘[l1]es[s]*[\\w$+$]*[\s+]*sh[ao0][l1][l1]*[\s+]*[rmn][ao0]t[\s+]*
    e[rmn]te[rmn][\s+]*up[ao0][rmn][\s+]*[\w+]*[\\s$+$]*
    [\\\~>/!\%\_,.-‘"\’()\$?@\#\\d:;]*[\s+]*su[rmn]f[ao0][\w+]*’
   ```
   (e) "Within (d) feet w w land (no surface use at all)"
   ```
   r‘withi[rmn][\s+]*\w+[\s+]*[(\{\[)\}\]]*[\\\~>/!\%\_,.-‘"\’\$?@\#]*[\d+]*
    [\\~>/!\%\_,.-‘"\’()\$?@#]*[\s+]*[\d+]*[\\~>/!\%\_,.
    ‘"\’\$?@\#]*[\s+]*[\d+]*[(\{\[)\}\]]*[\s+]*fe[e]*t[\s+]*
    [\w+]*[\s+]*[\w+]*[\s+]*[l1][ao0][rmn]d’,
   ```
2. Surface Damage: "Lessee shall pay for damage"
   ```
   r‘[l1]es[s]*[\w+]*[\s+]*sh[ao0][l1][l1]*[\s+]*p[ao0][v\\/y]
    [\s+]*[\w+]*[\s+]*d[ao0][rmn][ao0]g[\w+]*’
   ```

[35] Before employing the OCR software to convert to text, the pdfs must first be converted to jpeg files using Ghostscript software.

After extracting relevant text from the documents, the data were cleaned further using regular expression functions and quantified into a binary form[36] useful in the analysis using STATA. Finally, the auxiliary clauses were matched to the observational lease data[37] using a record number assigned by the county clerk office.

A.2 Leases Merged to Properties

Each lease observation in the data is matched to a specific parcel of property located in Tarrant County Texas, and this is achieved through string matches between the lease and housing data that are based on similar addresses, buyer, seller and owner names, and other location attributes. The lease data includes the addresses of the grantors and grantees along with their names. Similarly, the housing data provides addresses and buyer, seller, and owner names.

Each field, like address, is parsed into simpler categories like street name, city name, and state, for example. The data is cleaned for common miss-spellings and superfluous characters. Miss-spellings are corrected by embedding a user defined function, *strgroup* ,[38] into a function designed for this project that groups similarly spelled words together and converges the spelling to the most common instances within some specified threshold. The number of allowed spelling changes is controlled by a standard measure of string differences, or Levenshtein distance, which counts the number of changes necessary to convert one word to a different word.[39] The project specific function assumes that the correct spelling is the spelling used most frequently across both data sets, it applies strgroup iteratively, and it assigns the correct spelling to all misspelled words before the data sets are merged. The function is used to clean each string component of the address, along with first, middle, and last names of buyers, seller, and owners.

Using the cleaned data sets, the merge code ranks the merges based on stringency of the match by matching using variable combinations that differ in restrictiveness. The first merge requires that the data sets match on all address fields and a first and last name. A less strict match would relax whether the street type matches (ex. road, street, boulevard, etc...). The code runs through a series of roughly fifty matches on the data, keeping the most strict merge feasible for each lease.

A.2.1 Split estates

Split estates are not directly identified in the data set, and a comparison of names and dates describing who and when the leases were signed relative to the transaction dates allow for a variable that approximates whether the parcels' mineral estate rights are severed from the surface estate. As described above, each parcel is matched to a lease using a series of string matches between descriptions of addresses and the signers of the leases. Once matched, the names on the leases can be compared to the buyers and sellers of the house located on the parcel through time using the Tarrant County Appraiser data and DataQuick. The dates the house was sold and a lease was signed can be used as clues, as well.

[36] For example, a lease has a surface damage clause $\{0, 1\}$.

[37] Observational data includes information about the grantors (landowners) and grantees (firms), royalty rates, and term length; the data available through Drilling Info.

[38] In particular, *strgroup* , designed by Julian Reif at the University of Chicago, measures the levenshtein distance between each word in a data set and groups those word based on provided restrictions governing the maximum string distance. This function calculates the Levenshtein distance between all of the strings being fed to the function, and normalizes by the length, or ?edit distance?, of the smallest string in the group. If the normalized distance is less than a specified threshold, the strings are grouped together and output into a new group variable.

[39] For example, "lessor" and "lessee" would have a Levenshtein distance of two as one needs to change the "or" to "ee" in order to make the two words identical.

Between the datasets, we first identify perfect matches between the names of the individuals signing the leases and the buyers and sellers listed in the housing databases. We then proceed to identify close spellings using the Levenshtein string distance measure. Using this function, we can find those names that are nearly the same and differ likely from data entry errors across data sets. After identifying the name matches, we can then compare the transaction and lease dates to approximate whether the transacted houses have split estates. The intuition of this final step is that sellers signing leases at a date after the transaction date are likely to have split the estate when they sold it to the new buyers, otherwise the name on the lease would match that of the buyers. A secondary split estate identifier tags those houses with owner names matching lease signers but not matching the buyer or seller of the house.

B Appendix: Lease Clause Description

Primary Clauses

1. Lease Term: The term of the lease often includes both primary and secondary terms in units of months or years. The primary term is the length of time allowed to drill a well and begin producing. Given that the well is producing in paying quantities, or is capable of producing in paying quantities, the primary term rolls-over into the secondary term of the lease, which remains in effect as long as the well is producing. A typical lease term ranges between three and five years. A longer lease term is generally considered to be bad from the point of view of the lessor, as it allows the lessee to hold mineral rights for a longer period without paying royalties.
2. Royalty: The fraction of earnings from the producing well paid to the lessors owning royalty interest in the well based on the acreage contribution of an individual lease to the producing well.
3. Bonus: A signing bonus is often negotiated at a per acre increment and is exchanged between the lessor and lessee at the time when the lease is signed. Bonus payments are frequently not reported in recorded lease agreements.

Auxiliary Clauses

1. Environmental Clause: Leases clause limiting the types of substances allowed for use in executing exploration and extraction activities. This clause encourages the use of safeguards to prevent contamination of soil, water, and surface and subsurface strata. Includes limits the use of hazardous substances as defined by the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), and additional pollution restrictions and control mechanisms required by lessees

2. Surface Damage: In general, the lessee is not required to compensate the lessor for reasonable and necessary use of the surface to access the mineral estate. Lessors can negotiate on a variety of dimensions; however, it is important to note that in large urban areas many of these dimensions are regulated through municipal ordinance. Lease may require lessees to restore the property to the state before the well was drilled through surface damage/cleanup language.

3. Freshwater Protection: Lease may prohibit disposal, including discharge of oil field brines, geothermal resource waters, or other mineralized waters, or other drilling fluids, into any watercourse or drainage-way, including any drainage ditch, dry creek, flowing creek, river, or

other body of surface water. Lease may prohibit use of pit for storage of oil or oil products, oil field fluids, or oil and gas wastes.

4. Free Surface Water Use: Lessees have a right to use the surface and sub-surface water during drilling operations like hydraulic fracturing or secondary operations, and some leases more explicitly state the free use of water, oil, and gas produced on the land for operations.

5. Saltwater Disposal: Restricts that firms not locate a saltwater disposal well on the property.

6. Compressor Station Restriction: Requires that firms not locate a compressor station within a specified distance of a residence.

7. Injection Fluid: In the preamble, the leases list the rights of the lessee, which in this case includes the right inject gas, water, and other fluids and air into the subsurface strata.

8. No Surface Access: Leases can restrict the access a firm has to the mineral estate via the surface estate. Lease may stipulate that all acreage must be pooled especially if the lessee owns a smaller tract of land. Other language may constrain where a well can be drilled in the context of a pooled agreement, for example, stating that the minerals may only be accessed through a well drilled on another pooled tract of land (might also be interpreted as a surface protection clause).

9. Subsurface (Perpetual) Easement: Leases may state that the lessor gives the right to use the property to access wells (with pipelines) located on theirs and other property which may not be used to develop the lease, and that the easements can remain in place after the lease expires. This language is particularly relevant for gathering lines.

10. Legal bundle:

    (a) Indemnity: An indemnity clause shifts liability from the lessor to the lessee in the event that a third party claims negligence on the part of the lessor for lessee activities. The indemnity clause is strengthened by satisfying the "express negligence" rule; otherwise the court system is likely to not uphold the indemnity clause. This is achieved by including the phrase "including claims alleging that the lessor is guilty of negligence of other misconduct."

    (b) Vertical Pugh Clause: This clause relinquishes ownership of the mineral estate back to the lessor at the end of the primary term in the event the producing well is not drawing from that portion of the lease.

    (c) Title Defense: Imposes that the grantee assumes all responsibility for checking the title prior to signing the lease and for resolving any issues that arise with respect to the title without penalizing future royalties (owed to the grantor) until resolution or any other similar penalties.[40]

11. Attorney Fees: Lessor assumes responsibility for attorney fees that may arise from future negotiations.

12. Force Majeure: These clauses are often included to protect the lessee in the event of uncontrollable circumstances limiting or altogether halting operations on a well. To protect the

[40] There are several variants of "defend the title," and the one used in the analysis is the most protective of the landowner in the event that there are issues to resolve with respect to the title.

lessor, additional clauses limiting the extent of delay or the definition of force majeure can be included.

13. Post-Production Costs: Unless stipulated by the lease, post-production costs, like transportation and compression, might be deducted from the final royalty payment owed to lessors. Leases will often, to the benefit of lessees, contain language about royalty being calculated at the mouth of the well allowing courts leeway to rule in favor of deducting additional post-production costs. To protect property owners, lessors can add language constraining the post-production costs or stating that royalty be calculated at the point of sale.