Energy Boom to Doom: The Impact of Fracking on Deaths of Despair

Elle Marie Boyd

Economics Honors Thesis

Washington and Lee University

Advisor: Professor Katharine Shester

Committee Members: Professor Joseph Guse and Professor Alice Zhang

May 2022

Abstract

Since 1999, "deaths of despair"—deaths from drug overdoses, alcoholic liver disease, liver cirrhosis, and suicide—have driven increases in mortality for middle-age white Americans (Case and Deaton 2017). While the shale oil and gas boom in the early 2000s generally created positive short-term employment and income effects at the local level in shale communities, the boom has been associated with increased rates of crime, binge drinking, and exposure to pollutants. To the best of my knowledge, no study has investigated the relationship between fracking and deaths of despair. Using the fracking boom as a shock to local labor markets, I employ a difference-in-difference-in-differences model that compares changes in deaths of despair mortality in shale counties before and after the boom to the changes experienced by non-shale counties. I find that oil and gas producing shale counties in the post-2011 boom period experienced significantly higher deaths of despair mortality rates relative to the pre-2011 boom period, compared to those experienced by non-producing, non-shale counties. These findings support the traditional boomtown model and suggests that individuals, especially males between the ages of 25 and 54, in fracking communities are affected by non-pollution related mortality, which necessitates further research and policy attention.

JEL codes: I19, I31, O13, Q32, and Q33

Keywords: hydraulic fracturing, energy boom, traditional boomtown model, social disruption, deaths of despair.

*I thank Professor Katharine Shester and Professor Joseph Guse for their constant guidance and support throughout this year in addition to the resources and knowledge that they shared with me during this process. I also thank Professor Alice Zhang for her constructive comments and feedback that helped me to refine my analysis. Finally, I am grateful for the continued inspiration and encouragement from my fellow ECON 440 classmates, Sam Johnson, Olivia Jones, Jeremiah Kohl, and Brian Wickman, during this project.

I. Introduction and Background

Though unconventional extraction techniques like hydraulic fracturing (“fracking”) and horizontal drilling existed prior to the 21st century, the confluence of technological improvements, competitive energy prices, and changes to national environmental regulations in the early 2000s made the extraction of fuel deposits trapped in shale plays in the United States both feasible and profitable. As shale oil and gas production became economically viable, companies rushed to acquire land on shale deposits and secure drilling rights to the land—efforts referred to as a *land grab* (Jacquet and Kay 2014). Securing mineral and drilling rights serves as one form of capital investment made by energy companies and other industry players in shale-rich areas; market players also invest in local infrastructure projects, including the construction of pipelines and compressor stations (Brannstrom et al. 2016, Brundage et al. 2011, Murtazashvili 2017, Wang 2020). Capital and labor requirements vary significantly across the exploration, extraction, and production phases. During the pre-drilling and drilling phases of shale oil and gas production, contractors often rely on transient, young, male workers (Brundage et al. 2011, Hazboun and Mayer 2019). While some workers find short-term rentals in the area, other workers stay in collections of RVs and mobile homes near their work site, lending to the phrase “man camps.”

Fracking communities and their man camps have been criticized by local residents and media outlets for fostering alcoholism, drug addiction, prostitution, and gambling (Brannstrom et al. 2016). These observed social disamenities are similar to those documented by sociologists in energy boomtown communities beginning in the 1970s. Early studies on boomtowns, especially mining communities in the western United States, noted increased mental health caseloads, lower quality of community services, and increased reports of murder and grand larceny (Bacigalupi, Freudenburg, and Landoll-Young 1982; Albrecht and England 1984; Brookshire and D'Arge 1980). Their findings formed the "traditional boomtown model" or "social disruption hypothesis," which posits that the quality of life in a resource-rich area declines as a result of the sudden increase in the population following an energy boom (England and Albrecht 1984, Jacquet and Kay 2014). As newcomers come into the area, they place pressure on a community's infrastructure, housing supply, and its ability to provide goods and services like education and health care. The insufficient infrastructure and public services, along with skill mismatch and uneven job growth, can disrupt the wellbeing of the town's residents.

At the same time that fracking activity started to boom, alcohol and drug-related deaths and suicide—collectively referred to as "deaths of despair"—were rising across the United States, especially for middle-age white men without a college degree. Economists Anne Case and Angus Deaton (2017) hypothesize that cumulative socioeconomic disadvantages experienced by these individuals have contributed to the significant increase in deaths of despair mortality from 1999 onwards. The fracking boom serves as a shock to local labor markets in shale play communities. Since natural gas and oil in shale plays was largely inaccessible until the early 2000s, communities arguably developed independently of their location on a shale play. Therefore, using the fracking boom as a plausibly-exogenous socioeconomic shock to shale play communities, I examine the relationship between fracking and deaths of despair at the county level—a relationship that, to the best of my knowledge, has not been previously investigated in the economics literature.

While the traditional boomtown model suggests that the social disruption stemming from population increases and demographic changes during an energy boom should correspond to higher deaths of despair, conceptual models of deaths of despair pathways suggest that the positive income and employment effects of fracking should reduce deaths of despair in shale communities. To test these contrasting hypotheses, I employ a difference-in-difference model as well as a triple difference model using county-level data from 2001 to 2019. I find a significant and positive association between a county's location within a shale play and increases in deaths of despair between the pre-boom period (2001-2005) and two post-boom periods (2011-2016 and 2017-2019). Further, I find that oil and gas-producing shale counties experience significantly greater increases in deaths of despair for men and middle-age men in the 2011-2019 post-boom period relative to the pre-boom period than non-producing, non-shale counties. These results support the traditional boomtown model and suggest that individuals, especially males between the ages of 25 and 54, in fracking communities are affected by non-pollution related mortality, which necessitates further research and policy attention.

II. Literature Review

Fracking and Socioeconomic Outcomes

While the literature on resource booms and energy boomtowns is extensive, one subset of the literature that has emerged more recently focuses on the socioeconomic impact of fracking and horizontal drilling. Numerous studies have explored the short-term employment and income effects of fracking at the county level (Paredes, Komarek, and Loveridge 2014, Lee 2015, Bartik et al. 2019, Wang 2020). Researchers have found conflicting short-term results. Focusing on counties within the Marcellus Shale, Paredes, Komarek, and Loveridge (2014) do not find income or employment effects when they employ a propensity score matching model. However, when they use a panel-fixed effects model, the authors find significant employment effects—though they do not find significant income effects. Lee (2015) finds that gas wells generate larger income and employment effects than oil wells in Texas counties between 2009 and 2019, and Wang (2020) finds significant income and employment effects in Texas and New Mexico counties within the Permian Basin as a result of increased energy production volume. In a nation-wide study, Bartik et al. (2019) use a "prospectivity index" published by Rystad Energy, an energy consulting firm, as a measure of a county's potential fracking exposure. The index utilizes geological inputs to score the potential productivity of various areas within a given shale play. The authors divide counties into quartiles based on each county's Rystad score, and they find that counties in the top quartile experience significantly greater employment and income increases—driven by wage, rents, and dividend increases—after the use of fracking compared to lower-quartile counties in the same shale play.

These short-term impacts of the fracking boom on labor market demographics and earnings serve as possible mechanisms through which fracking may affect various socioeconomic outcomes. As discussed in Section I, the energy sector tends to be male-dominated, and most workers involved in the drilling process come from outside of the community (Hazboun and Mayer 2019). An increase in the male-to-female population ratio (or sex ratio) in a community experiencing a fracking boom may in turn impact the social dynamics in the area. Beleche and Cintina (2018) hypothesize that an increased sex ratio and higher earnings from unconventional drilling activity impact risk-taking behavior. They find that counties with unconventional gas activity in Pennsylvania experienced higher rates of sexually-transmitted diseases and prostitution-related arrests than counties without unconventional gas activity. The substantial population and demographic changes that a boomtown community experiences have also inspired researchers to study crime rates during a fracking boom. James and Smith (2017) hypothesize that while the increased demand for labor in communities during the energy boom in the mid-2000s brought new workers into a region, the region's number of police officers may not have experienced a proportional increase, resulting in a decrease in the probability of getting caught for a crime—in effect, lowering the cost of committing a crime. They find significant and positive crime effects for aggravated assault, auto theft, and larceny in post-shale boom countries. In contrast to the nation-wide study of James and Smith (2017), Lim (2018) examines the effects of the fracking boom on county-level crime in the Bakken shale play but finds similar significant positive effects of the shale oil boom on crime rates.

Other researchers use the fracking boom as an exogenous, positive shock on male earnings. Cascio and Narayan (2020) analyze the impact of fracking on high school dropout rates and find significantly higher dropout rates for male teens. Zuo, Scheiffer, and Buck (2019) also find that higher drilling activity corresponded to lower enrollment in 11^{th} and 12^{th} grade; moreover, they find that states with a lower tax rate on energy production experience greater enrollment decreases than those states with higher energy tax rates. Kearney and Wilson (2017) explore causality between improved economic outlooks for men and marriage and fertility rates in; they find that the positive income effect of the fracking boom for counties within shale plays between 2002 and 2012 is associated with a significant increase in both marital and non-marital births. Similarly, Hazboun and Mayer (2019) argue that men in the energy sector often have higher incomes than men who are not employed in the industry. Therefore, they hypothesize that the inequalities in earnings create a "masculinity crisis" among local men without oil and gas jobs, leading to a higher consumption of alcohol. Their results suggest variation in the effects of oil and gas production on levels of excessive alcohol consumption across states. For instance, while increased oil production in most states did not seem to be associated with county-level heavy drinking for males, Kansas and North Dakota experienced a positive association, while

Montana and Mississippi experienced a negative association. These results support the argument that not all communities impacted by energy booms experience homogenous effects.

Fracking and Mortality

In addition to the literature concerning fracking's impact on various socioeconomic outcomes, some researchers have explored pollution-related mortality for individuals living in nearby communities. Nduka (2019) examines cause-specific mortality from cardiovascular and respiratory diseases in Colorado counties during pre- and post-fracking periods (the latter being 1999-2015). Blomberg et al. (2020) find an association between unconventional oil and gas development and radiation exposure for nearby residents. Both Li (2020) and Bargagli-Stofi et al. (2022) use Cox proportional hazards and difference-in-difference models to analyze the impact of proximity to unconventional oil and gas wells on all-cause mortality for Medicare beneficiaries. They argue that air pollutants generated from oil and gas exploration increase the risk of mortality for the elderly living nearby. Traffic-related deaths in the context of fracking have also been considered; Xu and Xu (2020) find an association between high traffic volumes resulting from fracking activity and traffic deaths in North Dakota.

Deaths of Despair

One subset of mortality includes alcohol-related deaths, drug overdoses, and suicides—what economists Case and Deaton (2017) refer to as "deaths of despair." Though deaths of despair have been rising since 1990, Case and Deaton (2017) find significantly larger increases in deaths of despair since 1999, especially for middle-age white males. Pierce and Schott (2020) consider the passage of permanent normal trade relations (PNTR) with China in 2000 as a plausibly exogenous economic shock to U.S. counties and analyze the impact of PNTR on deaths of despair. They find a positive association between drug overdose mortality and PNTR exposure for whites, especially white males. Though the relationship between fracking and alcohol consumption, crime, risky behavior, mental health, and all-cause mortality have been considered (Hazboun and Mayer 2019, James and Smith 2017, Lim 2018, Beleche and Cintina 2018, Maguire and Winters 2017, Li 2020), few—if any—studies to my knowledge examine the relationship between fracking and deaths of despair. Yet, the fracking boom in the United States overlaps with the period of rising deaths of despair, and the comparison of shale play and mortality maps (figures 1, 2a, and 2b) suggest high mortality in regions with shale plays. This research contributes to the body of literature on fracking booms by examining a possible relationship between deaths of despair and fracking throughout different post-boom periods.

III. Theory and Conceptual Framework

The Traditional Boomtown Model

Sociological studies from the 1970s and 1980s on mining boomtowns form the basis of the traditional boomtown model's social disruption hypothesis. In his seminal work on the economic, institutional, and social problems facing boomtowns, John S. Gilmore (1976) uses the fictional town of Pistol Shot as an example to generate a framework of potential mechanisms through which energy booms can create problems for the local area. As a result of a coal mining boom, Pistol Shot's population triples, placing pressure on the community's existing infrastructure, labor and housing markets, and its ability to provide goods and services such as education and health care; furthermore, the entrance of newcomers into the area creates social tensions between them and residents (Gilmore 1976). Following Gilmore, other sociologists and economists began to investigate the social changes occurring in western U.S. boomtowns. Some of these early studies on boomtowns examine mental health clinic caseloads (Bacigalupi, Freudenburg, and Landoll-Young 1982) and the disruption of community ties (Albrecht and England 1984).

More recent studies investigate the economic and institutional impacts of energy booms. For instance, some researchers look for evidence of "resource curses"—social, economic, and environmental problems—that result from the discovery of a natural resource in the area (Uetela and Obeng-Odoom 2016). Others discuss the role of investment in urban infrastructure and governance during an energy boom (Cummings and Mehr 1977, Venables 2016). They argue that government officials face uncertainty when making investments in city infrastructure and services, given that population growth from the energy boom could be temporary. As localities are pressured by demands for increased levels of services by newcomers and are unable to meet the demands, social wellbeing and mental health may decline for residents of the area (Christopherson and Rightor 2012). As such, residents—especially those not employed in the energy sector—may turn to alcohol and drug use to cope with societal changes, or it may be the case that new workers in the area are more likely to drink and use drugs than the original residents. As a result, the traditional boomtown model predicts that fracking has a positive effect on deaths of despair.

Modifications to the Traditional Boomtown Model

Though the traditional boomtown model's social disruption hypothesis provides an initial framework through which we may analyze socioeconomic changes in communities impacted by energy booms, energy booms that rely on unconventional extraction technologies like fracking and horizontal drilling may differ from booms that rely on conventional extraction methods. Jeffrey Jacquet and David Kay (2014) highlight several unique aspects of fracking and horizontal drilling to challenge the assumptions of the traditional boomtown model. In particular, the boomtown model assumes that towns experiencing a boom are rural and isolated, that the extracted resource is spatially concentrated, and that there is a singular boom and a singular bust. However, fracking and horizontal drilling allow for oil and gas to be extracted in suburban—and even urban—areas. Furthermore, communities today may not experience the outcomes that the boomtown model predicts for rural areas, as technology improvements allow both rural and urban populations access to similar informational and cultural content (Jacquet and Kay 2014). Additionally, lease clauses and energy prices influence the timing differential between drilling and production. In order to secure drilling rights, firms will carry out minimal amounts of drilling and will return to the property to resume activity when energy prices are favorable (Jacquet and Kay 2014). Thus, shale play communities may experience multiple boom-and-bust cycles over the course of years rather than one boom and one bust, which would require the introduction of temporal and spatial variation into the boomtown model. Indeed, I find evidence of three different fracking boom periods after 2005, and I discuss these in Section V.

Deaths of Despair Pathways

Following Case and Deaton's work on deaths of despair and their proposal of cumulative disadvantage over one's life, researchers have sought to define a conceptual framework or mapping through which to examine deaths of despair. Copeland et al. (2019) propose a progression from economic stagnation to deaths of despair that permeates in different domains—including cognitive, emotional, behavioral, and biological—as shown in figure 3a. They posit that individuals exposed to globalization and automation are more likely to experience "risk factors for despair" such as declining incomes, disengagement from the labor force, and social isolation, which in turn supports despair, leading to diseases of despair and then to death (Copeland et al. 2019). Moreover, they argue that despair not only affects individuals but also social networks and communities. Indeed, some researchers argue that the boom-and-bust cycle can cause a community to experience collective trauma, especially when the relevant industry impacts community life (Abrahamson et al. 2018). Therefore, viewing fracking as a positive economic shock to a region, this conceptual framework suggests lower deaths of despair following a fracking boom.

However, the energy boom-and-bust cycle impacts various groups of people differently. While the fracking boom creates jobs, it does not create jobs for everyone. As discussed in Sections I and II, many of the workers employed during the fracking boom are male and come from outside of the community. Male workers who are not employed in the oil and gas industry may feel socially isolated or may experience a "masculinity crisis" during a fracking boom (Hazboun and Mayer 2019, Chen, Lusk, and Rehder 2021). The conceptual framework put forth by Chen, Lusk, and Rehder (2021) incorporates cognitive-behavioral models, the framework of moral injury, the "Precarious Manhood Theory," and the "Interpersonal Psychology Theory of Suicide" to highlight potential mechanisms of deaths of despair (figure 3b).

Relevant to the impacts of fracking on a community, theories of depression emphasize the role poverty and unemployment, especially for men in rural America, in the formation of negative self-worth and hopeless feelings about the future (Chen, Lusk, and Rehder 2021). For those without oil and gas jobs, individuals might perceive comparatively lower wages, leading to increased despair, alcohol and drug abuse, and possibly death. Moreover, the fracking boom could lead to increased price levels, which marginalizes local residents, leading to higher deaths of despair. This argument fits in with observations of pro-cyclical mortality in the United States (Case and Deaton 2017) and suggests that deaths of despair may rise during a fracking boom. Therefore, while the traditional boomtown model predicts a positive relationship between fracking and deaths of despair, conceptual frameworks for deaths of despair suggest an ambiguous relationship between the energy boom and mortality.

IV. Data

Shale Plays, Oil, and Natural Gas Data

The dataset contains county-year data from multiple sources for all counties in the contiguous United States—excluding the District of Columbia—from 2001 to 2019. Oil and gas production and well count data comes from Drilling Info (now Enverus). The data identifies operating wells, well spuds, and oil and gas production (in barrels and barrels of oil equivalent, respectively) by API well number and county. Due to endogeneity concerns regarding oil and gas production in a county, I follow James and Smith (2017) by identifying shale counties using location in a tight oil or shale gas play. Presumably, prior to fracking and horizontal drilling techniques, which made oil and gas trapped in shale plays more accessible and economical to drill, the presence of shale plays did not impact the social and economic development of nearby counties.

The Energy Information Administration (EIA) provides a list of U.S. counties in thirteen major shale plays.[1] The 325 counties in these thirteen major shale plays span sixteen states.[2] To identify counties in shale plays that are not classified as major shale plays by the EIA, I use ArcGIS technology to intersect county boundary shapefiles with tight oil and shale gas play boundary shapefiles. For county boundaries, I use the TIGER/Line 2019 County and Equivalent National Shapefile provided by the United States Census Bureau. For shale play boundaries, I use the Tight Oil and Shale Gas Play boundary shapefile from the EIA's U.S. Energy Atlas.

[1] The thirteen major shale plays identified by the EIA are: Fayetteville, Niobrara, New Albany, Haynesville, Antrim, Three Forks, Bakken, Wolfcamp, Utica, Marcellus, Woodford, Eagle Ford, Barnett.

[2] Arkansas, Colorado, Indiana, Louisiana, Michigan, Montana, North Dakota, Nebraska, New Mexico, Ohio, Oklahoma, Pennsylvania, South Dakota, Texas, West Virginia, and Wyoming.

Using both the EIA major shale counties and the shale counties identified in ArcGIS, I am able to identify 786 counties that have any geographical area within a shale play (shown in green in figure 1).

Mortality Data

I obtain both all-cause deaths and deaths of despair counts by county-year from the Current Final Multiple Cause of Death Data on CDC Wonder. To create mortality rates per 100,000 individuals, I use the National Cancer Institute's Surveillance, Epidemiology, and End Results Program (SEER) county population estimates. I collapse population estimates by gender and age group, which allows for analysis by subgroups of a county's population. Case and Deaton (2017) specify 41 International Classification of Diseases, 10^{th} revision codes (ICD-10 codes) for causes of death which they classify as deaths of despair. These underlying causes of death include accidental and undetermined-intent drug and alcohol poisonings, alcoholic liver disease and cirrhosis, and intentional self-harm (suicide).

One major limitation of the CDC Wonder cause of death data is that death counts are suppressed for counties with nine or fewer deaths. Moreover, not all counties have death counts for all years from 2001 to 2019. This becomes especially limiting when I analyze mortality for different sub-groups of the population, including men and men between the ages of 25 and 54. In the most restrictive sample (middle-age men), there are 452 counties with deaths of despair counts for men ages 25 to 54 for all 19 years. Of these counties, 93 (about 21%) are shale counties, excluding the 17 shale counties that did not experience any oil or gas production and did not have any wells for any year from 2001 to 2019. (To avoid underestimating the effect of oil and gas on outcome variables, I exclude these counties from the sample in the difference-in-difference model. However, I include these counties in the triple difference estimates, as I allow for differences in oil and gas production.) While the suppression of low death counts tends to eliminate small counties from the study, Jacquet and Kay (2014) argue that fracking differs from other energy booms in that extraction and production can occur in populous areas, not just rural, isolated areas as the traditional boomtown model assumes.

County Characteristics

County characteristic controls from the year 2000—before the fracking boom—come from the census (accessed through Social Explorer) and SEER. Recent research on disparities of working-age mortality rates carried out by the National Academy of Sciences, Engineering, and Medicine (2021) find race, ethnicity, economic status, and geography as drivers of large and widening mortality differences. Since the fracking boom and its subsequent oil and gas production often contribute, at least in the short run, to changes in population, income, and employment, I cannot include these characteristics in the model for all years, which would introduce endogeneity. However, since demographics and income are considered predictors of mortality (Couillard et al. 2021), it is important to include these variables in the model. Therefore, I include county characteristics from the year 2000 as “pre-controls.” Population and demographic controls include population density, male-to-female population ratio, demographic composition by race (black and white), and percentage of the population with highest educational attainment of high school or less at the county level. Socioeconomic controls include median housing values, median household income, unemployment rate, and percentage of the population that lives below poverty at the county level in the year 2000.

Table 1 contains the means of county-level pre-controls for producing and non-producing shale counties and for producing and non-producing non-shale counties from the year 2000. The mean population density for shale counties is much lower than that of non-shale counties. Shale counties (both producing and non-producing counties) experienced a higher percentage of the population over 25 years old with at most a high school education compared to non-shale counties in 2000. In both shale and non-shale counties, producing counties had on average about $4,000 lower median household income than non-producing counties in 2000. Producing counties had 14% of the population living in poverty in 2000, while non-producing counties had about 11% of the population living in poverty. The male-to-female ratio of producing counties was slightly higher than that in non-producing counties for both shale and non-shale counties. Each of the differences between shale and non-shale counties are statistically significant at the 99% confidence level (table 1). This suggests that shale and non-shale counties differed significantly in 2000 prior to the widespread use of unconventional drilling methods. However, the mortality time series plots (figures 4a and 4b) suggest approximately parallel trends for deaths of despair mortality for men and for middle-age men prior to 2006.

Tables 2a and 2b contain mortality rates, population counts, and energy production characteristics for shale and non-shale counties in 2001 and 2017 for counties with male deaths of despair counts and middle-age male deaths of despair counts, respectively, for all 19 years. In 2001 and 2017, shale counties in both samples experienced higher all-cause and deaths of despair mortality rates than non-shale counties, though both shale and non-shale counties experienced higher all-cause and deaths of despair mortality on average in 2017 than in 2001. Thus, the sample data reflects the national trend of rising mortality rates for men in middle age in the 21st century (Case and Deaton 2017). The well and production data also indicate that both shale and non-shale counties experience well activity and energy production. However, the mean well count, oil production, and gas production for non-shale counties are lower in 2017 than in

2001, while shale counties experienced higher well counts, oil production, and gas production in 2017 than in 2001.

V. Empirical Strategy

While some studies on the socioeconomic impacts of the fracking boom utilize levels of oil and gas production or total number of operating wells as explanatory variables (Hazboun and Mayer 2019), well location and production levels may be endogenous to local factors like property values, income, tax rates, and environmental policies (James and Smith 2017). In contrast, a county's being located within a shale play can serve as an exogenous county characteristic in the sense that shale oil and gas were inaccessible before fracking became economically viable in the early 2000s, and thus, shale gas production presumably had no impact on the county's development. Indeed, Kearney and Wilson (2017) argue that since these fuel deposits had essentially no economic value, "communities and economies grew and developed largely independent of shale play location." Therefore, I consider the fracking boom to be an exogenous shock to counties located within shale plays, and I utilize a modified triple difference model—one that allows for three different post-treatment time periods—to examine the impact of fracking on deaths of despair.

Both James and Smith (2017) and Cascio and Narayan (2020) employ difference-in-difference models to analyze the effect of fracking on socioeconomic factors and deem 2005 as the start of the fracking boom. The Energy Policy Act of 2005 exempted hydraulic fracturing fluids from regulations such as the Clean Water Act and Safe Drinking Water Act, which may have helped accelerate the use of fracking for oil and gas extraction (James and Smith 2017). Consequently, James and Smith use 2005 as their break year, letting years after 2005 represent post-boom years. Similarly, Cascio and Narayan, after using event study analysis to examine trends in employment growth and earnings in CZs with varying levels of shale reserves, refer to the years after 2005 as "post-fracking" years. They find that after 2005, CZs with higher levels of reserves saw higher rates of male employment than CZs with lower levels of shale reserves in the same state, and they find significant increases in earnings between 2006 and 2010 (Cascio and Narayan 2020).

Identifying Fracking Boom Periods

To determine the appropriate year to use as the start of the fracking boom, I investigate oil and natural gas production trends using the equation

$$y_{ct} = \beta_1 year_{t \neq 2001} + \beta_2 ShalePlay_c + \beta_3 (year_{t \neq 2001} \times ShalePlay_c) + \tau_c + \epsilon_{ct},$$

where y_{ct} represents per capita oil or natural gas production of county c in year t. $ShalePlay_c$ is a dummy variable equal to one when county c is in a shale play, $year_{t \neq 2001}$ is a dummy variable equal to one when the year equals t, and τ reflects census division fixed effects. 2001 is used as the base year. Figure 5 plots estimates of β_3, the interaction between the year dummy and shale play dummy, from 2001 to 2019, which provides insight into the relationship between a county's being located on a shale play and oil or gas production per capita in a given year and allows for the analysis of trends in shale county production relative to 2001 levels over time. For both oil and natural gas production, the coefficient estimates begin to generally increase following the slight "dip" in 2005. Both the magnitude and statistical significance of the estimates increase between 2005 and 2006, suggesting that the years after 2005 should be considered the "post-fracking" period.

However, the estimates indicate that shale counties experienced multiple booms and busts from 2006 to 2019, as Jacquet and Kay (2014) argue. For natural gas production, the first statistically-significant difference from 2001 production levels in shale counties relative to non-shale counties at the 95% confidence level occurs in 2011. Additionally, relative to 2011 natural gas production levels, natural gas production in shale counties for 2017, 2018, and 2019 are significantly different at the 99% confidence level, indicating another significant shift in production. Since the data used by Cascio and Narayan (2020) ends in 2015, they designate 2006-2010 and 2011-2015 as two post-fracking periods. Since I have data for the years 2001 to 2019, I build on Cascio and Narayan's analysis by specifying three post-fracking periods: 2006-2010, 2011-2016, and 2017-2019.

Difference-in-Difference Specification

To examine the impact of the shale boom on deaths of despair mortality and to motivate the triple difference specification, I first estimate a difference-in-difference model on three population samples: full population, male population, and middle-age male population. I define my treatment group as counties in the lower 48 states with some geographic area within a shale play, and I exclude shale counties that do not experience any oil or gas production nor have any wells drilled from 2001 to 2019. (I will allow for oil and gas production in the triple specification below). I define the control group as all other counties in the contiguous United States (excluding the District of Columbia) that do not have any area located on a shale play. Using the three post-fracking boom periods denoted above, I estimate a modified difference-in-difference equation:

$$\begin{aligned} y_{ct} = \alpha + \beta_1 ShalePlay_c + \beta_2\, PostBoom_t^{2006-2010} + \beta_3 PostBoom_t^{2011-2016} \\ + \beta_4 PostBoom_t^{2017-2019} + \beta_5 (ShalePlay_c \times PostBoom_t^{2006-2010}) \\ + \beta_6 (ShalePlay_c \times PostBoom_t^{2011-2016}) \\ + \beta_7 (ShalePlay_c \times PostBoom_t^{2017-2019}) + \lambda_t + \tau_c \\ + \gamma X'_{c,2000} + \theta\left(X'_{c,2000} \times year_t\right) + \epsilon_{ct}, \end{aligned}$$

where y_{ct} represents the death rate per 100,000 individuals in county *c* and year *t*. $ShalePlay_c$ is an indicator variable equal to one if the county is located in a shale play and equal to zero otherwise. The three $postBoom_t^{a-b}$ variables are dummy variables equal to one when year *t* is in the inclusive range a to b. $X'_{c,2000}$ is a set of county-level controls from the year 2000 that are plausibly exogenous to fracking (discussed in Section IV). Finally, $\theta\left(X'_{c,2000} \times year_t\right)$ represents pre-control linear time trends, and τ_c represents census division fixed effects. Division (τ) fixed effects control for time-invariant, region-specific factors that could impact mortality differently. Additionally, year (λ) fixed effects absorb nationwide time-varying mortality trends.

β_1 represents the estimated difference in death rates between shale and non-shale counties. β_2 estimates the average change in death rates in non-shale counties from 2001-2005 to 2006-2010, β_3 estimates the average change in death rates in non-shale counties from 2001-2005 to 2011-2016, and β_4 estimates the average change in death rates in non-shale counties from 2001-2005 to 2017-2019. β_5, β_6, and β_7 are the difference-in-difference coefficients of interest. β_5 represents the average difference in death rates from the pre-boom period (2001-2005) to the 2006-2010 post-boom period of shale countries relative to non-shale counties. Similarly, β_6 represents the average difference in death rates from the pre-boom period (2001-2005) to the 2011-2016 post-boom period of shale countries relative to non-shale counties, and β_7 represents the average difference in death rates from the pre-boom period (2001-2005) to the 2017-2019 post-boom period of shale countries relative to non-shale counties.

Triple Difference Specification

In the difference-in-difference model above, I exclude shale counties that do not experience any oil or gas production from 2001 to 2019 from the sample. However, a difference-in-difference-in-difference (or triple difference) model allows for the inclusion of varying degrees of oil and gas production for both shale and non-shale counties. In effect, there are two different control groups: non-producing counties and non-shale counties. The three "differences," then, are: production, location in a shale play, and time (before and after a fracking boom). This triple difference approach allows for the comparison of differences in county mortality rates by shale play location and by energy production before and after the fracking boom (Alsan and Wanamaker 2017). Underlying this specification is the assumption that in the absence of fracking, the average difference in mortality between producing shale and producing non-shale counties is equivalent to the average difference for mortality between non-producing shale and non-producing non-shale counties. The difference-in-difference estimates indicate that though most population sub-groups experienced changes in mortality following 2005, the most significant change in mortality occurred in the second post-boom period beginning in 2011. Therefore, I use 2011 as the break year in the triple-difference, though I also include estimates that use 2006 as the break year in tables 5a-c.

I estimate the equation

$$\begin{aligned} y_{ct} = {} & \alpha + \beta_1 ShalePlay_c + \beta_2 Production_c + \beta_3 PostBoom_t \\ & + \beta_4 (ShalePlay_c \times Production_c) + \beta_5 (ShalePlay_c \times PostBoom_t) \\ & + \beta_6 (Production_c \times PostBoom_t) \\ & + \beta_7 (ShalePlay_c \times Production_c \times PostBoom_t) + \lambda_t + \tau_c \\ & + \gamma X'_{c,2000} + \theta\left(X'_{c,2000} \times year_t\right) + \epsilon_{ct}, \end{aligned}$$

where y_{ct} and $ShalePlay_c$ are defined as they were in the difference-in-difference model, $Production_c$ is a dummy variable equal to one if the county has any non-zero values of oil and gas production (and well counts) in any year from 2001 to 2019, and $PostBoom_t$ equals one for years 2011 and onward. As in the difference-in-difference model, I include census division fixed effects, year fixed effects, a set of county pre-controls from the year 2000, and a control for pre-event county trends. β_7 is the interaction term of interest. β_1 represents the average difference in mortality between shale and non-shale non-production counties, and β_2 reflects the average difference in mortality between production and non-production non-shale counties. β_3 represents the average change in mortality for non-shale, non-producing counties from before 2011 to after 2011. β_5 represents the additional change in mortality rates for shale non-producing counties relative to non-shale non-producing counties. Similarly, β_6 represents the additional change in mortality rates for producing non-shale counties relative to non-producing non-shale counties.

VI. Results

Difference-in-Difference

The estimates from the difference-in-difference models are displayed in tables 3a and 3b. Table 3a contains the results for the balanced sample of counties with deaths of despair counts for men for all 19 years. Table 3b contains the results for the balanced sample of men in middle age (ages 25 to 54). Census division effects and year fixed effects are included in all specifications. Columns two and five include county-level pre-controls from 2000, and columns three and six include pre-control year trends. The positive and statistically significant coefficients on the interaction terms for shale play and the post-boom periods 2011-2016 and 2017-2019 indicate that shale counties in these periods experienced about 3 more male deaths of despair per 100,000 men in these two post-boom periods relative to the pre-boom period than non-shale counties. Though the estimated coefficient on the interaction between shale play and the post-boom period of 2006-2010 is slightly positive, it is not statistically significant, which indicates that shale counties experienced greater changes in deaths of despair relative to pre-boom levels in the two post-boom periods of 2011-2016 and 2017-2019 than in the post-boom period of 2006-2010.

When I restrict the sample to men between the ages of 25 and 54, I find greater changes in deaths of despair and all-cause deaths in post-boom periods (table 3b). Shale counties experienced about 9 more deaths of despair per 100,000 middle-age men in the post-boom periods of 2011-2016 and 2017-2019 relative to the pre-boom period compared to non-shale counties. These positive and statistically significant coefficients support the traditional boomtown model's social disruption hypothesis, which predicts that during an energy boom, alcohol and drug use rise, while mental health of both residents and newcomers deteriorates, suggesting a rise in alcohol- and drug-related deaths in addition to suicides.

Triple Difference

The difference-in-difference estimates suggest that while shale counties experienced higher deaths after 2006, they faced significantly higher changes in mortality relative to pre-boom years beginning in 2011. Therefore, in the triple difference specification, I denote 2011-2019 as the post-boom period. (For triple difference estimates that use 2006 as the break year, see tables 5a-c). Tables 4a-c contain estimates from the triple difference model for different subgroups of county population: full population, male population, and middle-age male (25-54). The triple difference estimates of the effect of living in a producing shale play county after 2011 relative to non-producing, non-shale counties support the traditional boomtown model. The triple interaction is positive for all subsets of the county population and generally grows in magnitude as the subsample grows more refined, suggesting that deaths of despair impact younger-to-middle age men more than other subgroups—which supports the findings of Case and Deaton (2017).

For the full sample, producing shale counties in the post-boom period experienced about 3 more deaths of despair per 100,000 individuals relative to the pre-boom period than non-producing, non-shale counties, which represents approximately 7% of the pre-2011 boom county sample mean. Further, producing shale counties experienced about 6 more deaths of despair per 100,000 men (approximately 11% of the pre-2011 sample mean) relative to the pre-2011 period than non-producing, non-shale counties did. Men between the ages of 25 and 54 experienced about 12 more deaths per 100,000 middle age men (about 16% of the pre-boom mean) relative to the pre-2011 period compared to the middle-age men in non-producing, non-shale counties in the pre-boom period. For all-cause mortality, the coefficient on the triple interaction term for the full sample is negative and statistically significant at the 99% confidence level, suggesting that all else equal, producing shale counties experienced fewer deaths in the post-2011 period relative to the pre-2011 period when compared to non-producing, non-shale. However, the estimate of the triple interaction term for the male sub-group is negative but statistically insignificant from zero, and it is positive but statistically insignificant from zero for the middle-age male subgroup. This suggests that other groups, including women and the elderly, which are excluded from the sub-groups I consider, are affected by fracking in ways that middle-age men may not be.

The estimates of the coefficient on the triple-interaction term from the triple difference model that uses 2006 as the break year are largely insignificant from zero, though their magnitudes generally align with those from the model that uses 2011 as the break year. For all three samples, the estimated triple interaction coefficient is positive for deaths of despair mortality and increases in magnitude as the subsamples grow more restrictive. Additionally, the triple interaction coefficient is negative and statistically significant at the 95% confidence level for all-cause mortality on the full sample, suggesting that producing shale play counties after

2006 experience on average 18 fewer deaths per 100,000 individuals relative to the pre-2011 period compared to non-producing, non-shale counties.

VII. Discussion and Conclusion

The modified difference-in-difference model allowed for the analysis of fracking's impact on deaths of despair mortality across multiple post-boom periods. The results support the argument that fracking has generated multiple boom-and-bust periods throughout the 21st century and suggest that shale counties experienced significantly larger increases in deaths of despair mortality in the two later post-boom periods (2011-2016 and 2017-2019) relative to the pre-boom period (2001-2005) than non-shale counties. A triple difference model allowed for the inclusion of oil and natural gas production into the analysis. Triple difference estimates also support the traditional boomtown model, as producing shale counties experienced significantly greater increases in deaths of despair in the post-2011 period relative to the pre-2011 period than non-producing, non-shale counties.

The positive relationship between oil and gas production, location within a shale play, and increases in county deaths of despair mortality could be facilitated by multiple mechanisms. Fracking jobs are largely filled by working-age males, which leads to the question of whether energy-sector workers or non-energy sector workers and residents are driving the higher rates of deaths of despair mortality after the fracking boom. Previous boomtown literature argues that there may be differences between the behaviors of those employed and not employed in the energy sector. Future research should be conducted that differentiates between deaths of those employed in the energy sector and those not employed in the energy sector, which could imply a skill-mismatch story and provide policy implications that target workers of various sectors. Other limitations of this study include the suppression of death counts for counties with fewer than nine deaths in any year and the subsequent exclusion of counties that had any missing death counts for any year from 2001 and 2019. Future research should use the full, confidential cause of death data from the CDC to allow for the inclusion of more counties in the analysis.

My results support the findings of Case and Deaton (2017) and Pierce and Schott (2020) that certain groups of individuals—specifically men and men in midlife—are at greater risk for deaths of despair than other groups. The alarming rise in deaths of despair since the turn of the century necessitates greater awareness of the mental health of all individuals in our communities. No life is more valuable than another, and no death is less important than another.

References

Abrahmason, Daniel, Tammy A. Barnes, Sarah Beckmann, Iva GreyWolf, Jane M. Hamel-Lambert, Jameson K. Hirsch, Teresa LaFromboise, Scott S. Meit, Michael R. Rosmann, Emily M. Selby-Nelson, and K. Bryant Smalley. 2018. "Psychosocial Impact of Fracking: a Review of the Literature on the Mental Health Consequences of Hydraulic Fracturing." *International Journal of Mental Health and Addiction* 16: 1-15.

Albrecht, Stan L., and J. Lynn England. 1984. "Boomtowns and Social Disruption." *Rural Sociology* 49 (2): 230-46.

Alsan, Marcella, and Marianne Wanamaker. 2018. "Tuskegee and the Health of Black Men." *The Quarterly Journal of Economics* 133 (1): 407-55. https://doi.org/10.1093/qje/qjx029.

Angrist, Joshua D., and Jörn-Steffen Pischke. 2008. "Parallel Worlds: Fixed Effects, Differences-in Differences, and Panel Data." From *Mostly Harmless Econometrics*: 221-47.

Bacigalupi, Linda M., William R. Freudenburg, and Cheryl Landoll-Young. 1982. "Mental Health Consequences of Rapid Community Growth: A Report from the Longitudinal Study of Boomtown Mental Health Impacts." *Journal of Health and Human Resources Administration* 4 (3): 334-52.

Bartik, Alexander W., Janet Currie, Michael Greenstone, and Christopher R. Knittel. 2019. "The Local Economic and Welfare Consequences of Hydraulic Fracturing." *American Economic Journal: Applied Economics* 11 (4): 105-155. https://doi.org/10.1257/app.20170487.

Beleche, Trinidad, and Inna Cintina. 2018. "Fracking and Risky Behaviors: Evidence from Pennsylvania." *Economics and Human Biology* 31: 69-82. https://doi.org/10.1016/j.ehb.2018.08.001.

Blomberg, Annelise J., Brent A. Coull, Petros Koutrakis, Longxiang Li, Joel D. Schwartz, and John D. Spengler. 2020. "Unconventional Oil and Gas Development and Ambient Particle Radioactivity." *Nature Communications* 11 (5002): 1-8. https://doi.org/10.1038/s41467-020-18226-w.

Bargagli-Stoffi, Falco J., Annelise J. Blomberg, Brent A. Coull, Francesca Dominici, Petros Koutrakis, Joy Lawrence, Longxiang Li, Joel D. Schwartz, John D. Spengler, and Yaguang Wei. 2022. "Exposure to Unconventional Oil and Gas Development and All-Cause Mortality in Medicare Beneficiaries." *Nature Energy* 7: 177-85. https://doi.org/10.1038/s41560-021-00970-y.

Borlu, Yetkin, Leland Glenna, and Kai A. Schafft. 2013. "The Relationship Between Marcellus Shale Gas Development in Pennsylvania and Local Perceptions of Risk and Opportunity." *Rural Sociology* 78 (2): 143-66.

Brabant, Sarah, and Bob Gramling. 1986. "Boomtowns and Offshore Energy Impact Assessment: The Development of a Comprehensive Model." *Sociological Perspectives* 29 (2): 177-201.

Brannstrom, Christian, Michael Ewers, Matthew Fry, and Trey Murphy. 2018. "Economic-Development Stakeholder Perspectives on Boomtown Dynamics in the Eagle Ford Shale, Texas." *Geographical Review* 108 (1): 24-44.

Brookshire, David S., and Ralph C. D'arge. 1980. "Adjustment Issues of Impacted Communities or, Are Boomtowns Bad?" *Natural Resources Journal*, 20 (3): 523-46.

Brundage, Tracy L., Jeffrey Jacquet, Timothy W. Kelsey, James R. Ladlee, Janice Lobdell, Jeffrey F. Lorson, Larry L. Michael, and Thomas B. Murphy. 2011. "Pennsylvania Statewide Marcellus Shale Workforce Needs Assessment." Marcellus Shale Education & Training Center: 1-60.

Buck, Steven, Jack Schieffer, and Na Zuo. 2019. "The Effect of the Oil and Gas Boom on Schooling Decisions in the U.S." *Resource and Energy Economics* 55: 1-23.

Burfoot-Rochford, Ian, Daniella Hall, Erin McHenry-Sorber, and Kai A. Schafft. 2018. "Busted Amidst the Boom: The Creation of New Insecurities and Inequalities within Pennsylvania's Shale Gas Boomtowns." *Rural Sociology* 83 (3): 503-31.

Butikofer, Aline, Antonio Dalla-Zuanna, and Kjell G. Salvanes. 2018. "Breaking the Links: Natural Resource Booms and Intergenerational Mobility." Norwegian School of Economics: 1-79.

Cascio, Elizabeth U., and Narayan, Ayushi. 2020. "Who Needs A Fracking Education? The Educational Response to Low-Skill-Biased Technological Change." *ILR Review*: 1-34.

Case, Anne, and Angus Deaton. 2017. "Mortality and Morbidity in the 21st Century." *Brookings Papers on Economic Activity*, BPEA Conference Drafts, March 23-24, 2017. https://www.brookings.edu/wp-content/uploads/2017/03/6_casedeaton.pdf.

Chen, Jason I., Jaimie Lusk, and Kristoffer Rehder. 2021. "Deaths of Despair: Conceptual and Clinical Implications." *Cognitive and Behavioral Practice* 28: 40-52.

Christopherson, Susan, and Ned Rightor. 2011. "How Shale Gas Extraction Affects Drilling Localities: Lessons for Regional and City Policy Makers." *Journal of Town & City Management* 2 (4): 1-19.

Copeland, William E., E. Jane Costello, Kenneth A. Dodge, Lauren M. Gaydosh, Kathleen Mullan Harris, Sherika N. Hill, Lilly Shanahan, and Annekatrin Steinhoff. 2019. "Does Despair Really Kill? A Roadmap for an Evidence-Based Answer." *American Journal of Public Health* 109 (8): 854-858. doi: 10.2105/AJPH.2019.305016.

Couillard, Benjamin K., Christopher L. Foote, Kavish Gandhi, Ellen Meara, and Jonathan Skinner. 2021. "Rising Geographic Disparities in US Mortality." *Journal of Economic Perspectives* 35 (4): 123-146. https://doi.org/10.1257/jep.35.4.123.

Cummings, Ronald G., and Arthur F. Mehr. 1977. "Investments for Urban Infrastructure in Boomtowns." *Natural Resources Journal* 17 (2): 223-40.

Cunningham, Scott. 2021. *Causal Inference: The Mixtape.* https://mixtape.scunning.com/.

Gilmore, John S. 1976. "Boom Towns May Hinder Energy Resource Development." *Science* 191 (4227): 535-540.

Hazboun, Shawn Olson, and Adam Mayer. 2019. "Does Fracking Drive You to Drink? Unconventional Oil and Gas Production and Alcohol Consumption in U.S. Counties." *The Extractive Industries and Society* 6: 823-30.

Hornbeck, Richard. 2012. "The Enduring Impact of the American Dust Bowl: Short- and Long-Run Adjustments to Environmental Catastrophe." *American Economic Review* 102 (4): 1477-1507.

http://dx.doi=10.1257/aer.102.4.1477.

Jacquet, Jeffrey B., and David L. Kay. 2014. "The Unconventional Boomtown: Updating the Impact Model to Fit New Spatial and Temporal Scales." *Journal of Rural and Community Development* 9 (1): 1-23.

James, Alexander, and Brock Smith. 2015. “There Will Be Blood: Crime Rates in Shale-Rich U.S. Counties.” *Journal of Environmental Economics and Management* 84: 125-52.

Kearney, Melissa S., and Riley Wilson. 2017. “Male Earnings, Marriageable Men, and Nonmarital Fertility: Evidence from the Fracking Boom.” National Bureau of Economic Research, *Working Paper 23408*: 2-52.

Komarek, Timothy, Scott Loveridge, and Dusan Paredes. 2015. “Income and Employment Effects of Shale Gas Extraction Windfalls: Evidence from the Marcellus Region.” *Energy Economics* 47: 112-20.

Lee, Jim. 2015. “The Regional Economic Impact of Oil and Gas Extraction in Texas.” *Energy Policy* 87: 60-71.

Li, Longxiang. 2020. “The Links Among Unconventional Oil and Gas Development, Particle Radioactivity and Morality.” Doctoral dissertation, Harvard T.H. Chan School of Public Health. https://dash.harvard.edu/handle/1/42676034.

Lim, Siew Hoon. 2018. “Does Shale Energy Development Mean More Crime? The Case of the Bakken Oil Boom.” *Growth and Change* 49 (3): p. 413-41.

Maguire, Karen, and John V. Winters. 2017. “Energy Boom and Gloom? Local Effects of Oil and Natural Gas Drilling on Subjective Well-Being.” *Growth and Change* 48 (4): 590-610.

Mason, Charles F., Lucija A. Muehlenbachs, and Sheila M. Olmstead. 2015. “The Economics of Shale Gas Development.” *Fondazione Eni Enrico Mattei (FEEM)*: 1-38.

Murtazashvili, Ilia. 2017. “Institutions and the Shale Boom.” *Journal of Institutional Economics* 13 (1): 189-210.

National Academies of Sciences, Engineering, and Medicine. 2021. High and Rising Mortality Rates Among Working-Age Adults. Washington, DC: The National Academies Press. https://doi.org/10.17226/25976.

Nduka, Uzoma C. 2019. "Hydraulic Fracturing and Cause-Specific Mortality: A Multicity Comparative Epidemiological Study." PhD Dissertation, Walden University.

Obeng-Odoom, Franklin, and Pedro Uetela. 2016. "Natural Gas and Socio-Economic Transformation in Mozambique: Some Preliminary Evidence." *The Journal of Energy and Development* 41 (1/2): 47-66.

Pierce, Justin R., and Peter K. Schott. 2020. "Trade Liberalization and Mortality: Evidence from US Counties." *American Economic Review: Insights* 2, no. 1 (March): 47-64. https://doi.org/10.1257/aeri.20180396.

Perez-Sindin, Xaquin S. 2021. "Are Energy Megaprojects Socially Disruptive? Assessing the Impacts of the As Pontes Fossil Fueled Power Plant in Spain." *Energy Research & Social Science* 80 (102229). https://doi.org/10.1016/j.erss.2021.102229.

Venables, Anthony J. 2016. "Using Natural Resources for Development: Why Has It Proven So Difficult?" *Journal of Economic Perspectives* 30 (1): 161-84.

Wang, Haoying. 2020. "The Economic Impact of Oil and Gas Development in the Permian Basin: Local and Spillover Effects." *Resources Policy* 66: 1-9.

Xu, Minhong, and Yilan Xu. 2020. "Fraccidents: The Impact of Fracking on Road Traffic Deaths." *Journal of Environmental Economics and Management* 101. https://doi.org/10.1016/j.jeem.2020.102303.

List of Tables and Figures

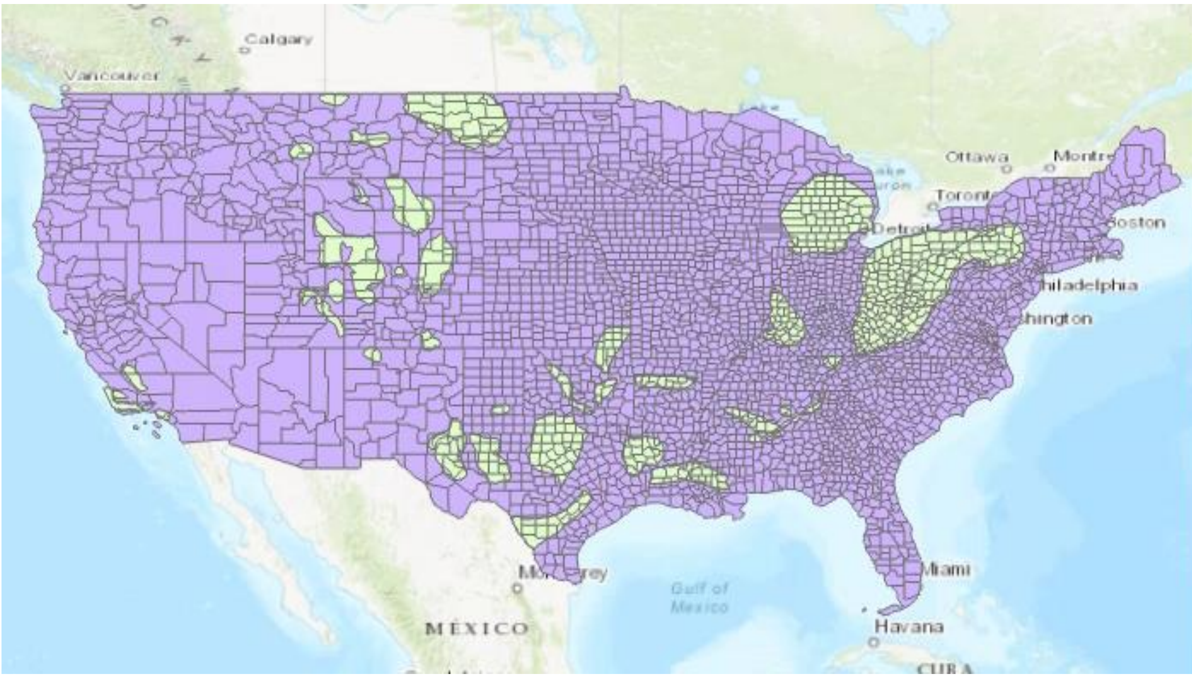

Figure 1. Location of Tight Oil and Shale Gas Plays in the Lower 48 United States

Notes: This map shows U.S. counties that are located on tight oil and shale gas plays in the contiguous United States. The green polygons represent counties with any area on a shale play. There are 786 such counties. This figure was made by the author in ArcGIS using the TIGER/Line 2019 County and Equivalent National Shapefile and the Tight Oil and Shale Gas shapefile from the U.S. Energy Atlas (EIA).

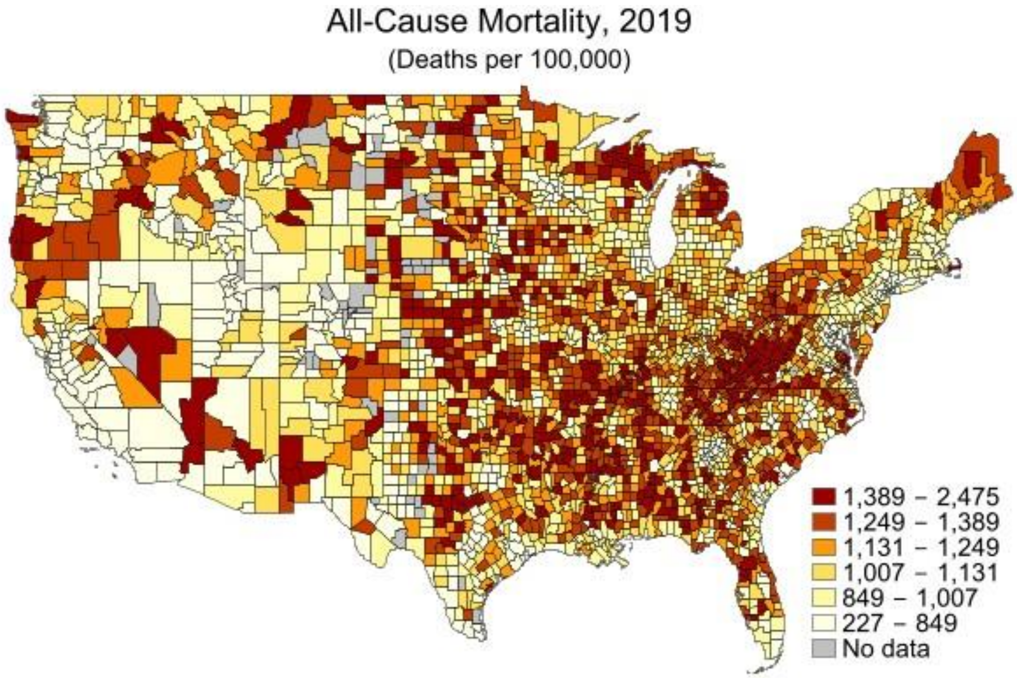

Figure 2a. County All-Cause Mortality, 2019

Notes: This map shows all-cause mortality (deaths per 100,000 individuals) in U.S. counties in 2019. Cause of death data comes from CDC Wonder, and population estimates comes from SEER. Mortality rates were calculated by the author.

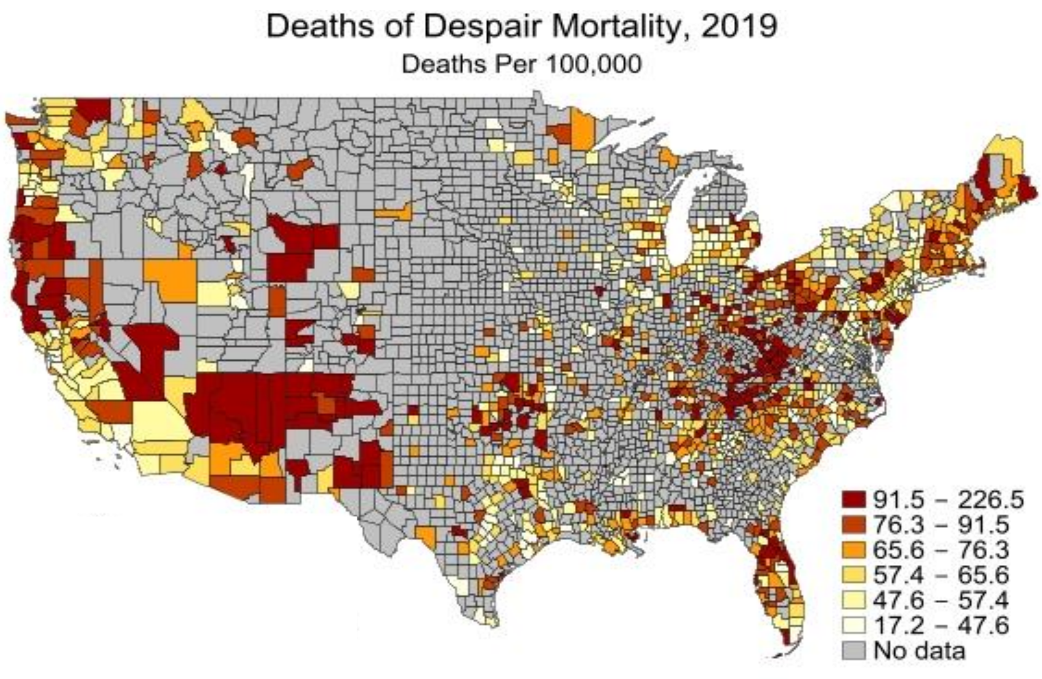

Figure 2b. County Deaths of Despair Mortality, 2019

Notes: This map shows deaths of despair mortality (deaths of despair per 100,000 individuals) in U.S. counties in 2019. Cause of death data comes from CDC Wonder, and population estimates comes from SEER. Mortality rates were calculated by the author. Counties with no data are counties with 9 or fewer deaths of despair in 2019.

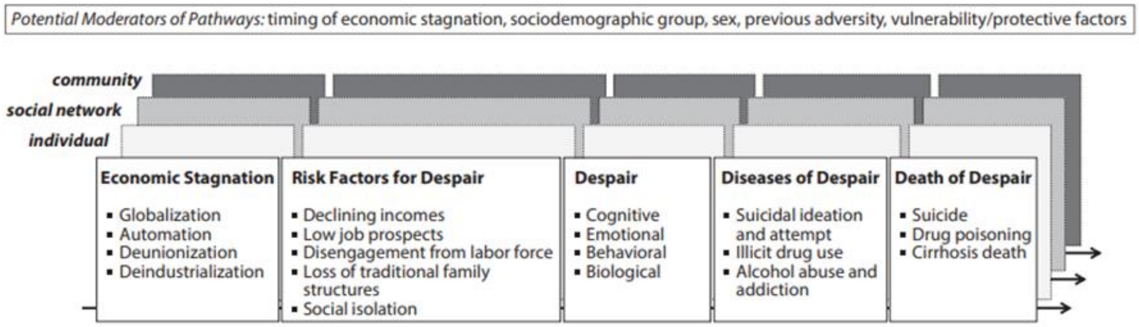

Figure 3a. Deaths of Despair Roadmap Proposed by Copeland et al. (2019)

Source: Copeland, William E., E. Jane Costello, Kenneth A. Dodge, Lauren M. Gaydosh, Kathleen Mullan Harris, Sherika N. Hill, Lilly Shanahan, and Annekatrin Steinhoff, 2019, "Does Despair Really Kill? A Roadmap for an Evidence-Based Answer," *American Journal of Public Health* 109 (8): 854-858. doi: 10.2105/AJPH.2019.305016.

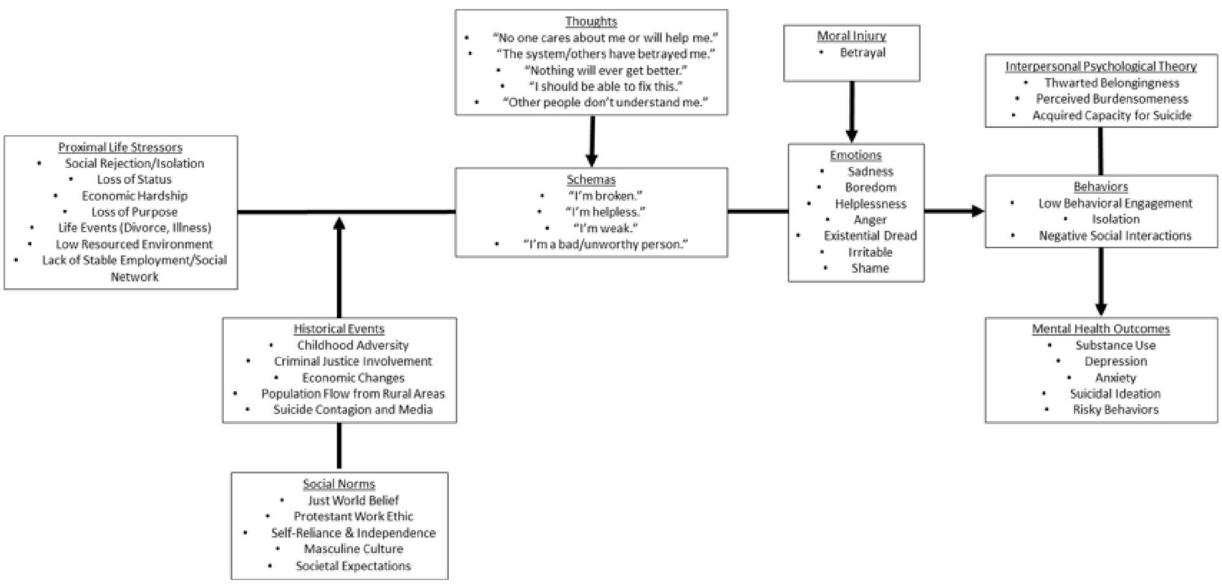

Figure 3b. Conceptual Model of Deaths of Despair Mechanisms Proposed by Chen, Lusk, and Rehder (2021)

Source: Chen, Jason I., Jaimie Lusk, and Kristoffer Rehder, 2021, "Deaths of Despair: Conceptual and Clinical Implications," *Cognitive and Behavioral Practice* 28: 40-52.

Table 1. County Pre-Control Characteristics, 2000

Variables	Shale Counties: Producing	Shale Counties: Non-Producing	Non-Shale Counties: Producing	Non-Shale Counties: Non-Producing	T-Test (Shale vs. Non-Shale)
Population Density	132.67	127.21	319.22	271.53	t = 9.4062
	(364.50)	(153.95)	(3,172.87)	(1,233.07)	
Median Household Income	32,487	36,630	33,581	36,934	t = 34.8690
	(7,552)	(8,760)	(8,223)	(9,138)	
Median Value of Owner-Occupied Housing Units	69,640	81,613	74,586	87,910	t = 32.6035
	(31,977)	(37,253)	(48,528)	(41,416)	
Unemployment Rate (Percent)	6.57	5.60	5.90	5.48	t = -32.509
	(2.56)	(2.70)	(2.94)	(2.58)	
Percent Living in Poverty	14.66	11.07	14.34	11.44	t = -33.8665
	(5.91)	(6.04)	(6.38)	(5.38)	
Percent White	89.93	91.98	87.76	87.18	t = -19.531
	(13.61)	(14.29)	(15.65)	(16.31)	
Percent Black	7.18	5.71	9.18	10.41	t = 22.1803
	(12.29)	(11.32)	(14.77)	(15.67)	
Male-to-Female Ratio	0.988	0.983	0.985	0.983	t = -4.4192
	(0.101)	(0.060)	(0.078)	(0.085)	
Median Age	37.27	37.38	36.73	37.55	t = 1.316
	(3.78)	(3.71)	(4.07)	(3.94)	
Percent HS or Less	60.06	59.54	57.51	56.41	t = -3.071
	(10.90)	(10.33)	(11.47)	(11.08)	
Observations	643	118	593	1,689	Degrees of Freedom: 57,815

Notes: This table contains the means and standard deviations of select county characteristics from the year 2000. The data comes from Social Explorer and SEER population estimates. The column on the far right contains t-test results for the differences between shale and non-shale county means. The differences in mean tests suggest that shale and non-shale counties differed in the year 2000 (prior to the fracking boom).

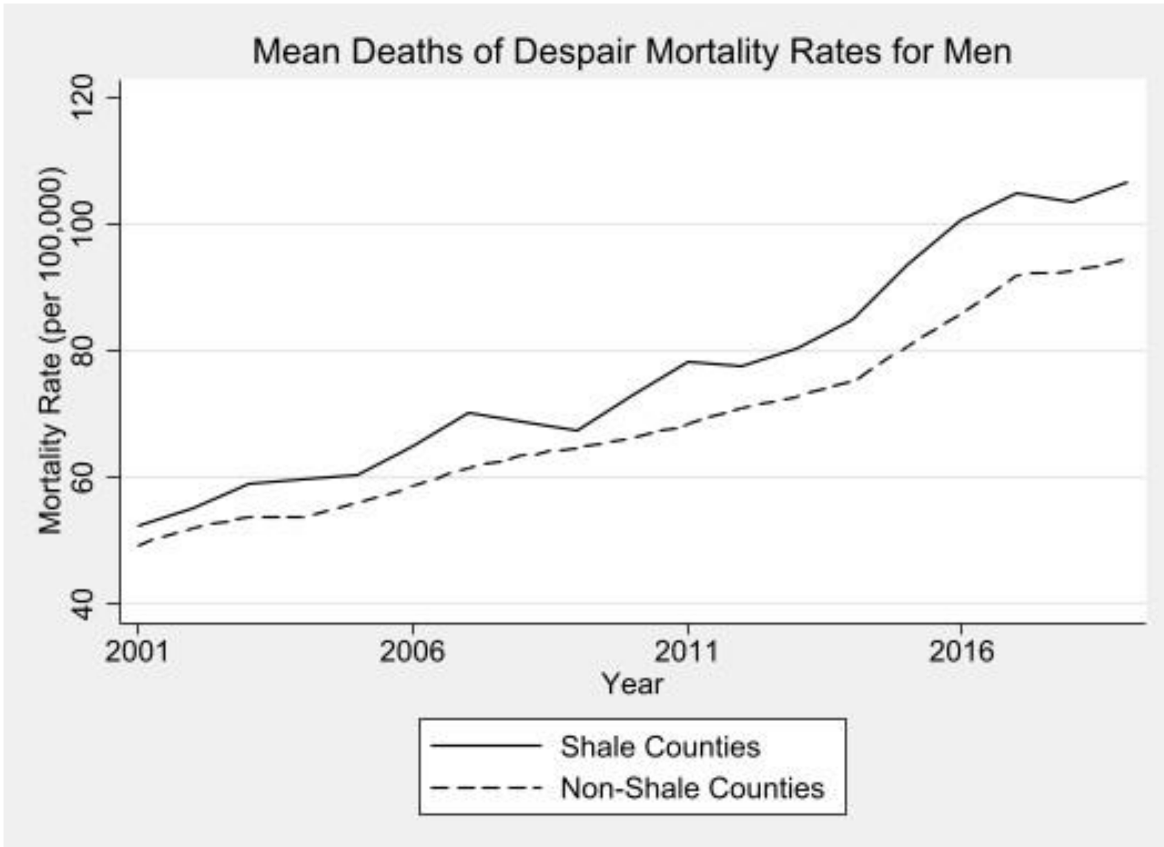

Figure 4a. Deaths of Despair Trends for Men, 2001-2019

Notes: This graph shows the average deaths of despair per 100,000 men by shale and non-shale counties from 2001 to 2019. The sample includes 179 shale counties and 617 non-shale counties with male deaths of despair counts for all 19 years. Male deaths of despair mortality rates for shale and non-shale counties were trending similarly prior to 2005, supporting the parallel trend assumption behind the difference-in-difference and triple difference models.

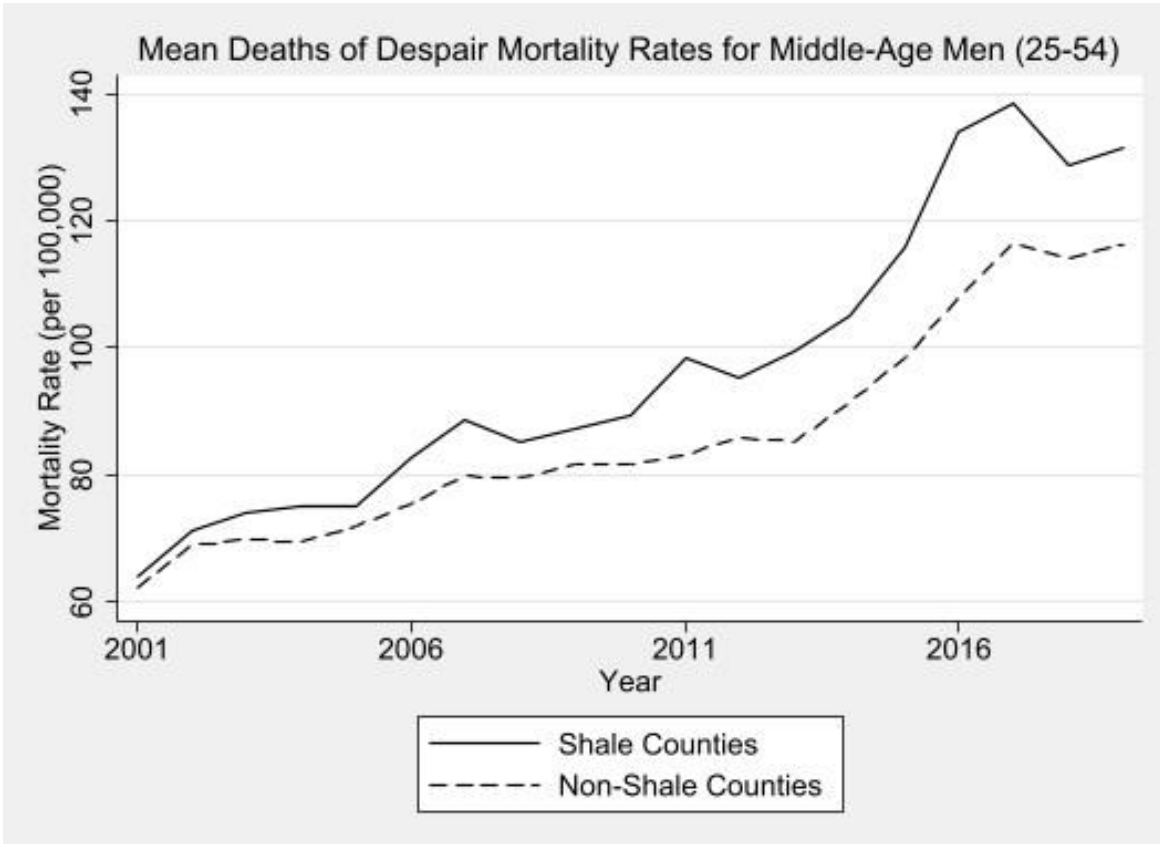

Figure 4b. Deaths of Despair Trends for Men in Midlife (25-54), 2001-2019

Notes: This graph shows the mean deaths of despair per 100,000 men between the ages of 25 and 54 by shale and non-shale counties from 2001 to 2019. The sample includes 93 shale counties and 359 non-shale counties with middle-age male deaths of despair counts for all 19 years. As with figure 4a, the deaths of despair mortality rates for shale and non-shale counties were trending similarly prior to 2005, supporting the parallel trend assumption behind the difference-in-difference and triple difference models.

Table 2a. Male Mortality and Production in Shale and Non-Shale Counties, 2001 and 2017

	2001		2017	
Variables (Means)	**Shale Counties**	**Non-Shale Counties**	**Shale Counties**	**Non-Shale Counties**
All-Cause Mortality Rate (per 100,000)	950.53 (242.06)	883.80 (215.50)	1,044.35 (285.14)	952.71 (239.06)
Deaths of Despair Mortality Rate (per 100,000)	36.29 (13.33)	34.02 (11.72)	76.21 (30.75)	66.02 (23.14)
All-Cause Mortality Rate for Men (per 100,000)	947.45 (244.63)	889.11 (234.07)	1,075.78 (300.28)	995.92 (267.54)
Deaths of Despair Mortality Rate for Men (per 100,000)	52.40 (21.69)	49.26 (17.42)	104.78 (42.58)	92.07 (32.63)
Male Population (in thousands)	151.19 (396.11)	136.92 (212.15)	168.71 (421.61)	160.70 (245.91)
Total Population (in thousands)	307.83 (802.81)	279.85 (434.14)	342.43 (856.11)	327.78 (501.11)
Annual Well Spuds Drilled	42.47 (84.81)	2.43 (12.11)	24.40 (86.87)	0.52 (2.94)
Well Count	1,293.72 (3,333.29)	40.04 (174.67)	1,560.60 (3,766.44)	32.88 (157.86)
Oil Production Per Capita (Barrels of Oil Per Person)	15.03 (71.75)	1.29 (9.38)	25.39 (145.39)	0.55 (3.43)
Gas Production Per Capita (Barrels of Oil Equivalent Per Person)	65.75 (239.07)	4.22 (24.57)	100.64 (312.72)	1.98 (12.29)
Observations	179	617	179	617

Notes: This table contains mortality and production data for counties with male all-cause death counts and male deaths of despair counts for all 19 years. This sample excludes 32 shale counties that did not have any oil or natural gas production, nor any wells or well spuds drilled, for any year between 2001 and 2019.

Table 2b. Middle-Age Male Mortality and Production for Shale and Non-Shale Counties, 2001 and 2017

	2001		2017	
Variables	**Shale Counties**	**Non-Shale Counties**	**Shale Counties**	**Non-Shale Counties**
All-Cause Mortality Rate (per 100,000)	889.97 (235.91)	847.21 (207.24)	963.72 (263.35)	892.73 (212.07)
Deaths of Despair Mortality Rate (per 100,000)	34.33 (10.69)	33.71 (11.00)	72.93 (29.29)	64.48 (21.33)
All-Cause Mortality Rate for Men (per 100,000)	881.22 (231.31)	852.77 (228.29)	991.07 (269.42)	931.57 (236.89)
Deaths of Despair Mortality Rate for Men (per 100,000)	48.70 (17.51)	48.79 (16.55)	101.64 (41.28)	90.37 (29.71)
All Cause-Mortality Rate for Men Ages 25-54 (per 100,000)	322.02 (92.79)	320.51 (99.87)	367.02 (134.42)	331.27 (111.67)
Deaths of Despair Mortality Rate for Men Ages 25-54 (per 100,000)	63.84 (28.44)	62.26 (25.33)	138.57 (83.20)	116.55 (49.91)
Male Ages 25-54 Population (in thousands)	114.25 (239.85)	92.39 (116.97)	117.82 (246.42)	98.74 (128.41)
Male Population (in thousands)	255.92 (529.42)	206.46 (256.20)	285.29 (561.16)	241.72 (296.41)
Total Population (in thousands)	521.46 (1,072.41)	422.42 (524.13)	580.05 (1,139.10)	493.51 (603.62)
Annual Well Spuds Drilled	48.68 (101.29)	2.67 (14.04)	31.75 (105.72)	0.53 (2.84)
Well Count	1,573.82 (4,312.39)	36.49 (164.52)	1,867.96 (4,811.85)	30.36 (146.17)
Oil Production Per Capita (Barrels of Oil Per Person)	13.39 (62.57)	0.55 (2.48)	24.83 (141.76)	0.29 (1.56)
Gas Production (Barrels of Oil Equivalent Per Person)	63.35 (259.68)	2.46 (11.31)	76.92 (285.38)	0.84 (3.68)
Observations	93	359	93	359

Notes: This table contains mortality and production data for counties with all-cause death counts and deaths of despair counts for men between the ages of 25 and 54 for all 19 years. This sample excludes 17 shale counties that did not have any oil or natural gas production nor any wells or well spuds drilled for any year between 2001 and 2019.

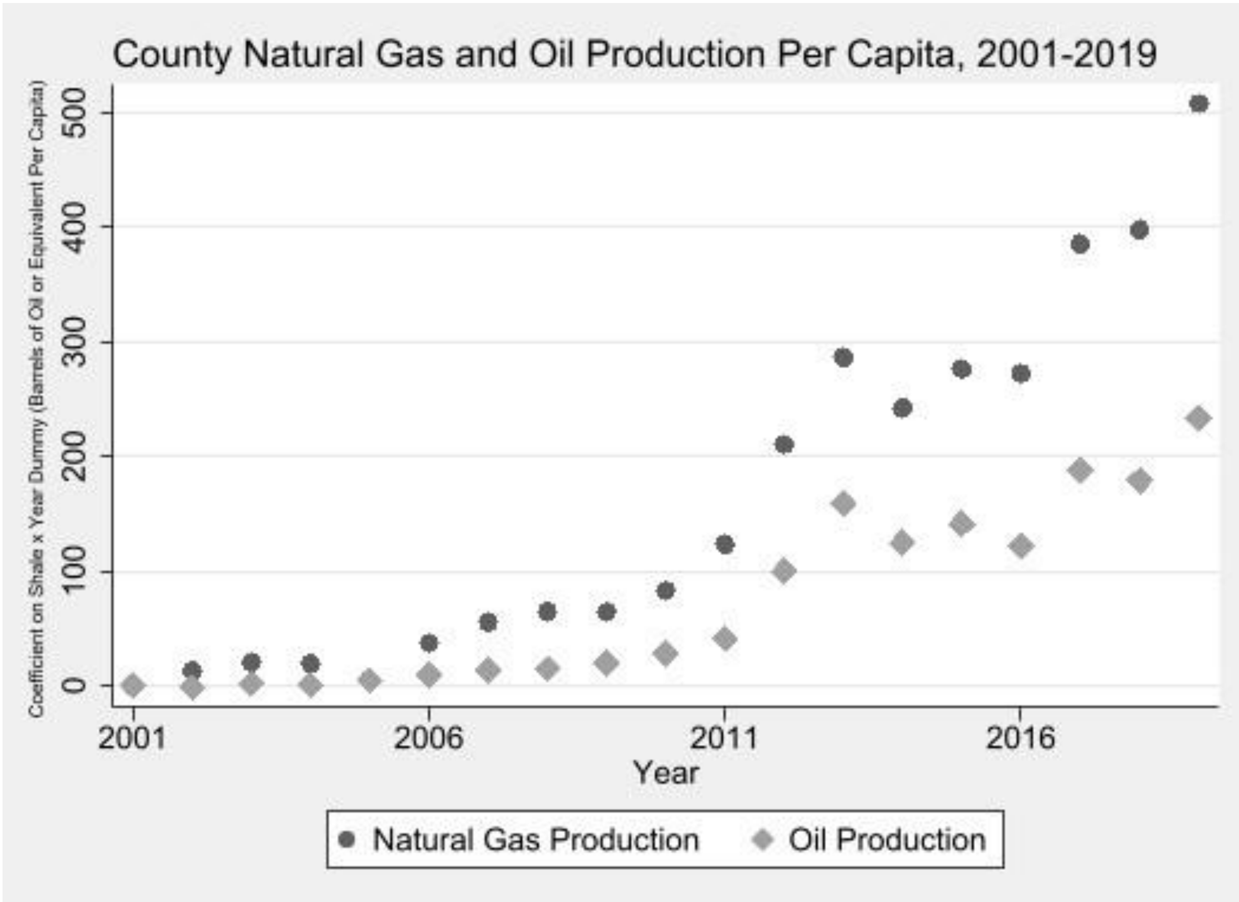

Figure 5. County Oil and Gas Production Per Capita Trends, 2001-2019

Notes: This graph plots the estimates of the average effects of the interaction between year and the shale play indicator variable on both oil and natural gas production per capita relative to 2001 levels. This allows for the analysis of production per capita trends in shale counties over time. These estimates suggest three distinct post-fracking boom periods: 2006-2010, 2011-2016, and 2017-2019.

Table 3a. Difference-in-Difference Estimates, All-Male Sample

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	All-Cause Mortality Rate (per 100,000)	All-Cause Mortality Rate (per 100,000)	All-Cause Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)
Post-Boom (2006-2010)	-10.29	-10.29**	654.5***	17.40***	17.40***	222.6***
	(12.53)	(5.024)	(98.15)	(1.370)	(1.068)	(20.89)
Post-Boom (2011-2016)	84.31***	84.31***	1,193***	37.85***	37.85***	380.1***
	(12.50)	(5.012)	(163.5)	(1.367)	(1.065)	(34.78)
Post-Boom (2017-2019)	125.4***	125.4***	1,457***	45.60***	45.60***	456.4***
	(12.64)	(5.069)	(196.1)	(1.383)	(1.077)	(41.74)
Shale Play	62.62***	-17.75***	-6.781*	5.820***	-1.014	1.177
	(9.414)	(3.817)	(3.842)	(1.030)	(0.811)	(0.818)
Shale Play x Post-Boom (2006-2010)	13.80	13.80***	5.966	1.640	1.640	0.0762
	(13.05)	(5.232)	(5.190)	(1.427)	(1.112)	(1.104)
Shale Play x Post-Boom (2011-2016)	16.80	16.80***	0.351	5.988***	5.988***	2.704**
	(12.49)	(5.009)	(5.073)	(1.366)	(1.065)	(1.079)
Shale Play x Post-Boom (2017-2019)	26.12*	26.12***	2.613	7.632***	7.632***	2.940**
	(15.06)	(6.041)	(6.180)	(1.648)	(1.284)	(1.315)
Constant	935.9***	4,193***	3,527***	37.15***	62.06**	-143.6***
	(11.61)	(120.8)	(154.1)	(1.269)	(25.68)	(32.78)
Census Division FE	X	X	X	X	X	X
Year FE	X	X	X	X	X	X
2000 County Pre-Controls		X	X		X	X
2000 County Pre-Controls x Year			X			X
Observations	796	796	796	796	796	796
R-squared	0.109	0.857	0.861	0.304	0.577	0.588

Notes: This table contains difference-in-difference estimates using the all-male sample of counties with male deaths of despair counts for all 19 years. Shale Play is an indicator variable equal to 1 if the county has any geographical area within a shale play. Post-Boom is an indicator variable equal to 1 in the years indicated. The unit of observation is the county, and the sample includes men of all ages and races. 2000 pre-controls include population and demographic county characteristics (population density, male-to-female population ratio, demographic composition by race, and percentage of the population with highest educational attainment of high school or less) and socioeconomic controls (median housing values, median household income, unemployment rate, and percentage of the population that lives below poverty). *** p<0.01, ** p<0.05, * p<0.1

Table 3b. Difference-in-Difference Estimates, Middle-Age Male Sample

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	All-Cause Mortality Rate (per 100,000)	All-Cause Mortality Rate (per 100,000)	All-Cause Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)
Post-Boom (2006-2010)	-12.36*	-12.36***	296.1***	19.92***	19.92***	366.3***
	(6.690)	(4.093)	(86.03)	(2.642)	(2.146)	(45.50)
Post-Boom (2011-2016)	7.350	7.350*	521.7***	48.03***	48.03***	625.4***
	(6.676)	(4.084)	(143.3)	(2.637)	(2.141)	(75.79)
Post-Boom (2017-2019)	6.792	6.792*	624.4***	53.97***	53.97***	747.0***
	(6.745)	(4.126)	(172.0)	(2.664)	(2.163)	(90.95)
Shale Play	6.877	-11.15***	-6.282**	5.114**	-1.943	0.394
	(5.251)	(3.243)	(3.201)	(2.074)	(1.700)	(1.693)
Shale Play x Post-Boom (2006-2010)	16.78**	16.78***	13.30***	3.603	3.603	1.936
	(7.216)	(4.415)	(4.316)	(2.850)	(2.315)	(2.283)
Shale Play x Post-Boom (2011-2016)	25.80***	25.80***	18.51***	12.57***	12.57***	9.066***
	(6.909)	(4.227)	(4.189)	(2.729)	(2.216)	(2.216)
Shale Play x Post-Boom (2017-2019)	28.76***	28.76***	18.34***	13.84***	13.84***	8.838***
	(8.333)	(5.098)	(5.087)	(3.291)	(2.673)	(2.691)
Constant	316.2***	2,029***	1,720***	55.33***	668.5***	321.5***
	(6.251)	(105.5)	(133.7)	(2.469)	(55.29)	(70.72)
Census Division FE	X	X	X	X	X	X
Year FE	X	X	X	X	X	X
2000 County Pre-Controls		X	X		X	X
2000 County Pre-Controls x Year			X			X
Observations	452	452	452	452	452	452
R-squared	0.159	0.686	0.702	0.250	0.506	0.523

Notes: This table contains difference-in-difference estimates using the sample of counties with deaths of despair counts for men between the ages of 25 and 54 for all 19 years. Shale Play is an indicator variable equal to 1 if the county has any geographical area within a shale play. Post-Boom is an indicator variable equal to 1 in the years indicated. The unit of observation is the county, and the sample includes men of all ages and races. 2000 pre-controls include population and demographic county characteristics (population density, male-to-female population ratio, demographic composition by race, and percentage of the population with highest educational attainment of high school or less) and socioeconomic controls (median housing values, median household income, unemployment rate, and percentage of the population that lives below poverty). *** p<0.01, ** p<0.05, * p<0.1

Table 4a. Triple Difference Estimates Using 2011 As Break Year, Full Sample

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	All-Cause Mortality Rate (per 100,000)	All-Cause Mortality Rate (per 100,000)	All-Cause Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)
Mean (Before 2011)	1,028.17	1,028.17	1,028.17	41.80	41.80	41.80
Shale Play x Post-Boom x Production	-13.99	-16.43**	-17.26***	3.226**	3.226***	3.299***
	(11.69)	(6.679)	(6.644)	(1.531)	(1.197)	(1.183)
Shale Play x Post-Boom	20.38**	21.81***	18.33***	1.265	1.265	0.00555
	(8.492)	(4.855)	(4.841)	(1.283)	(1.004)	(0.996)
Shale Play x Production	11.15	5.616	6.012	0.810	-0.511	-0.546
	(8.185)	(4.687)	(4.657)	(1.065)	(0.836)	(0.823)
Post-Boom x Production	-11.42*	-10.86***	-12.04***	0.144	0.144	-1.253**
	(6.770)	(3.867)	(3.956)	(0.720)	(0.563)	(0.576)
Constant	965.3***	6,549***	7,610***	22.36***	36.29**	-38.99
	(7.327)	(92.56)	(164.8)	(0.782)	(15.51)	(27.53)
Census Division FE	X	X	X	X	X	X
Year FE	X	X	X	X	X	X
2000 County Pre-Controls		X	X		X	X
2000 County Pre-Controls x Year			X			X
Observations (Counties)	3,043	3,043	3,043	1,090	1,090	1,090
R-squared	0.104	0.705	0.710	0.333	0.592	0.607

Notes: This table contains triple difference estimates using two samples, one with all-cause deaths for all 19 years and one with deaths of despair counts for all 19 years. Shale Play is an indicator variable equal to 1 if the county has any geographical area within a shale play. Post-Boom is an indicator variable equal to 1 for the years 2011 to 2019. Production is an indicator variable equal to 1 if the county experienced any wells drilled or had any oil and gas production in any year from 2001 to 2019. The unit of observation is the county, and the sample includes men of all ages and races. 2000 pre-controls include population and demographic county characteristics (population density, male-to-female population ratio, demographic composition by race, and percentage of the population with highest educational attainment of high school or less) and socioeconomic controls (median housing values, median household income, unemployment rate, and percentage of the population that lives below poverty). *** p<0.01, ** p<0.05, * p<0.1

Table 4b. Triple Difference Estimates Using 2011 As Break Year, All-Male Sample

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	All-Cause Mortality Rate (per 100,000)	All-Cause Mortality Rate (per 100,000)	All-Cause Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)
Mean (Before 2011)	896.14	896.14	896.14	58.98	58.98	58.98
Shale Play x Post Boom x Production	-10.53	-10.53	-8.302	4.780*	4.780**	6.194***
	(23.73)	(9.481)	(9.371)	(2.594)	(2.024)	(1.998)
Shale Play x Post-Boom	22.36	22.36***	10.29	1.048	1.048	-0.791
	(20.24)	(8.088)	(8.014)	(2.213)	(1.727)	(1.709)
Shale Play x Production	-9.778	-9.945	-11.00*	-2.689	-0.815	-1.485
	(16.51)	(6.619)	(6.524)	(1.805)	(1.413)	(1.391)
Post-Boom x Production	1.550	1.550	-2.164	-0.146	-0.146	-2.854***
	(10.52)	(4.204)	(4.338)	(1.150)	(0.898)	(0.925)
Constant	926.3***	4,283***	4,147***	35.57***	79.80***	-60.09
	(11.47)	(118.5)	(210.0)	(1.253)	(25.30)	(44.79)
Census Division FE	X	X	X	X	X	X
Year FE	X	X	X	X	X	X
2000 County Pre-Controls		X	X		X	X
2000 County Pre-Controls x Year			X			X
Observations	828	828	828	828	828	828
R-squared	0.116	0.859	0.864	0.307	0.578	0.593

Notes: This table contains triple difference estimates for the sample of counties with deaths of despair counts for men of all ages for all 19 years. Shale Play is an indicator variable equal to 1 if the county has any geographical area within a shale play. Post-Boom is an indicator variable equal to 1 for the years 2011 to 2019. Production is an indicator variable equal to 1 if the county experienced any wells drilled or had any oil and gas production in any year from 2001 to 2019. The unit of observation is the county, and the sample includes men of all ages and races. 2000 pre-controls include population and demographic county characteristics (population density, male-to-female population ratio, demographic composition by race, and percentage of the population with highest educational attainment of high school or less) and socioeconomic controls (median housing values, median household income, unemployment rate, and percentage of the population that lives below poverty). *** p<0.01, ** p<0.05, * p<0.1

Table 4c. Triple Difference Estimates Using 2011 As Break Year, Middle-Age Male Sample

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	All-Cause Mortality Rate (per 100,000)	All-Cause Mortality Rate (per 100,000)	All-Cause Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)	Deaths of Despair Mortality Rate (per 100,000)
Mean (Before 2011)	325.11	325.11	325.11	75.06	75.06	75.06
Shale Play x Post-Boom x Production	7.296	7.296	8.743	10.41**	10.41**	12.18***
	(13.13)	(8.020)	(7.819)	(5.193)	(4.203)	(4.114)
Shale Play x Post-Boom	17.56	17.56**	8.525	5.485	5.485	1.497
	(11.23)	(6.858)	(6.685)	(4.440)	(3.594)	(3.518)
Shale Play x Production	-42.19***	-15.15***	-15.84***	-0.894	3.444	2.606
	(9.149)	(5.617)	(5.458)	(3.617)	(2.944)	(2.872)
Post-Boom x Production	-8.363	-8.363**	-6.695*	-6.101***	-6.101***	-6.266***
	(5.651)	(3.451)	(3.547)	(2.234)	(1.808)	(1.866)
Constant	302.1***	2,001***	1,299***	52.29***	664.3***	415.5***
	(6.260)	(103.7)	(179.7)	(2.475)	(54.35)	(94.56)
Census Division FE	X	X	X	X	X	X
Year FE	X	X	X	X	X	X
2000 County Pre-Controls		X	X		X	X
2000 County Pre-Controls x Year			X			X
Observations	469	469	469	469	469	469
R-squared	0.171	0.691	0.710	0.250	0.509	0.536

Notes: This table contains triple difference estimates for the sample of counties with deaths of despair counts for men in middle age for all 19 years. Shale Play is an indicator variable equal to 1 if the county has any geographical area within a shale play. Post-Boom is an indicator variable equal to 1 for the years 2011 to 2019. Production is an indicator variable equal to 1 if the county experienced any wells drilled or had any oil and gas production in any year from 2001 to 2019. The unit of observation is the county, and the sample includes men of all ages and races. 2000 pre-controls include population and demographic county characteristics (population density, male-to-female population ratio, demographic composition by race, and percentage of the population with highest educational attainment of high school or less) and socioeconomic controls (median housing values, median household income, unemployment rate, and percentage of the population that lives below poverty). *** p<0.01, ** p<0.05, * p<0.1

Table 5a. Triple Difference Estimates Using 2006 As Break Year, Full Sample

VARIABLES	(1) All-Cause Mortality Rate (per 100,000)	(2) All-Cause Mortality Rate (per 100,000)	(3) All-Cause Mortality Rate (per 100,000)	(4) Deaths of Despair Mortality Rate (per 100,000)	(5) Deaths of Despair Mortality Rate (per 100,000)	(6) Deaths of Despair Mortality Rate (per 100,000)
Mean (2001-2005)	1,028.17	1,028.17	1,028.17	37.75	37.75	37.75
Shale Play x Post-Boom x Production	-11.28	-13.95	-18.46**	2.128	2.128	2.167
	(14.95)	(8.558)	(8.513)	(1.736)	(1.358)	(1.340)
Shale Play x Post-Boom	19.49	21.56***	15.37**	0.883	0.883	-0.409
	(12.83)	(7.350)	(7.325)	(1.455)	(1.139)	(1.127)
Shale Play x Production	23.82*	-2.293	1.033	0.770	-0.551	-0.579
	(12.88)	(7.382)	(7.340)	(1.498)	(1.175)	(1.157)
Post-Boom x Production	-3.773	-2.925	7.788**	1.630**	1.630**	0.306
	(6.431)	(3.676)	(3.748)	(0.816)	(0.639)	(0.647)
Constant	965.5***	6,582***	7,603***	22.83***	36.76**	-41.31
	(7.492)	(92.55)	(164.7)	(0.798)	(15.52)	(27.54)
Census Division FE	X	X	X	X	X	X
Year FE	X	X	X	X	X	X
2000 County Pre-Controls		X	X		X	X
2000 County Pre-Controls x Year			X			X
Observations	3,043	3,043	3,043	1,090	1,090	1,090
R-squared	0.104	0.705	0.709	0.333	0.592	0.607

Notes: This table contains triple difference estimates using two samples, one with all-cause deaths for all 19 years and one with deaths of despair counts for all 19 years. Shale Play is an indicator variable equal to 1 if the county has any geographical area within a shale play. Post-Boom is an indicator variable equal to 1 for the years 2006 to 2019. Production is an indicator variable equal to 1 if the county experienced any wells drilled or had any oil and gas production in any year from 2001 to 2019. The unit of observation is the county, and the sample includes men of all ages and races. 2000 pre-controls include population and demographic county characteristics (population density, male-to-female population ratio, demographic composition by race, and percentage of the population with highest educational attainment of high school or less) and socioeconomic controls (median housing values, median household income, unemployment rate, and percentage of the population that lives below poverty). *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5b. Triple Difference Estimates Using 2006 As Break Year, All-Male Sample

VARIABLES	(1) All-Cause Mortality Rate (per 100,000)	(2) All-Cause Mortality Rate (per 100,000)	(3) All-Cause Mortality Rate (per 100,000)	(4) Deaths of Despair Mortality Rate (per 100,000)	(5) Deaths of Despair Mortality Rate (per 100,000)	(6) Deaths of Despair Mortality Rate (per 100,000)
Mean (2001-2005)	902.45	902.45	902.45	53.84	53.84	53.84
Shale Play x Post Boom x Production	-7.169	-7.169	-5.112	2.847	2.847	4.189*
	(26.91)	(10.75)	(10.61)	(2.942)	(2.297)	(2.265)
Shale Play x Post-Boom	21.70	21.70**	9.839	0.852	0.852	-1.036
	(22.96)	(9.170)	(9.072)	(2.510)	(1.959)	(1.936)
Shale Play x Production	-9.484	-9.651	-11.17	-2.522	-0.649	-1.638
	(23.23)	(9.293)	(9.166)	(2.540)	(1.986)	(1.956)
Post-Boom x Production	4.174	4.174	0.914	1.423	1.423	-1.179
	(11.93)	(4.766)	(4.863)	(1.305)	(1.018)	(1.038)
Constant	928.6***	4,285***	4,141***	36.00***	80.24***	-62.83
	(11.70)	(118.5)	(210.0)	(1.279)	(25.32)	(44.80)
Census Division FE	X	X	X	X	X	X
Year FE	X	X	X	X	X	X
2000 County Pre-Controls		X	X		X	X
2000 County Pre-Controls x Year			X			X
Observations	828	828	828	828	828	828
R-squared	0.116	0.859	0.864	0.306	0.578	0.593

Notes: This table contains triple difference estimates for the sample of counties with deaths of despair counts for men of all ages for all 19 years. Shale Play is an indicator variable equal to 1 if the county has any geographical area within a shale play. Post-Boom is an indicator variable equal to 1 for the years 2006 to 2019. Production is an indicator variable equal to 1 if the county experienced any wells drilled or had any oil and gas production in any year from 2001 to 2019. The unit of observation is the county, and the sample includes men of all ages and races. 2000 pre-controls include population and demographic county characteristics (population density, male-to-female population ratio, demographic composition by race, and percentage of the population with highest educational attainment of high school or less) and socioeconomic controls (median housing values, median household income, unemployment rate, and percentage of the population that lives below poverty). *** p<0.01, ** p<0.05, * p<0.1

Table 5c. Triple Difference Estimates Using 2006 As Break Year, Middle-Age Male Sample

VARIABLES	(1) All-Cause Mortality Rate (per 100,000)	(2) All-Cause Mortality Rate (per 100,000)	(3) All-Cause Mortality Rate (per 100,000)	(4) Deaths of Despair Mortality Rate (per 100,000)	(5) Deaths of Despair Mortality Rate (per 100,000)	(6) Deaths of Despair Mortality Rate (per 100,000)
Mean (2001-2005)	327.59	327.59	327.59	69.05	69.05	69.05
Shale Play x Post-Boom x Production	8.794	8.794	9.993	4.772	4.772	6.226
	(14.89)	(9.092)	(8.850)	(5.894)	(4.774)	(4.665)
Shale Play x Post-Boom	19.35	19.35**	10.37	6.635	6.635	2.532
	(12.73)	(7.775)	(7.567)	(5.040)	(4.082)	(3.988)
Shale Play x Production	-45.21***	-18.18**	-19.06**	0.522	4.860	3.788
	(12.86)	(7.874)	(7.654)	(5.091)	(4.134)	(4.034)
Post-Boom x Production	-6.391	-6.391	-4.318	-2.292	-2.292	-2.006
	(6.407)	(3.912)	(3.965)	(2.536)	(2.054)	(2.090)
Constant	303.8***	2,003***	1,290***	53.00***	665.0***	390.8***
	(6.371)	(103.7)	(179.5)	(2.522)	(54.44)	(94.60)
Census Division FE	X	X	X	X	X	X
Year FE	X	X	X	X	X	X
2000 County Pre-Controls		X	X		X	X
2000 County Pre-Controls x Year			X			X
Observations	469	469	469	469	469	469
R-squared	0.171	0.691	0.711	0.249	0.508	0.535

Notes: This table contains triple difference estimates for the sample of counties with deaths of despair counts for men in middle age for all 19 years. Shale Play is an indicator variable equal to 1 if the county has any geographical area within a shale play. Post-Boom is an indicator variable equal to 1 for the years 2006 to 2019. Production is an indicator variable equal to 1 if the county experienced any wells drilled or had any oil and gas production in any year from 2001 to 2019. The unit of observation is the county, and the sample includes men of all ages and races. 2000 pre-controls include population and demographic county characteristics (population density, male-to-female population ratio, demographic composition by race, and percentage of the population with highest educational attainment of high school or less) and socioeconomic controls (median housing values, median household income, unemployment rate, and percentage of the population that lives below poverty). *** p<0.01, ** p<0.05, * p<0.1