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Abstract

We investigate effects of plausibly exogenous variation in the value of oil and natural gas production in local economies on self-employment in the United States. We find that self-employment is procyclical, i.e. self-employment increases during a business cycle expansion and is reduced during a contraction. This effect comes entirely from unincorporated self-employed workers (in lieu of incorporated self-employment). We also find that self-employment explains an economically meaningful share of the employment adjustment; point estimates suggest that approximately 8 to 9 percent of the employment adjustment comes from unincorporated self-employed individuals - a group that makes up about 6 percent of total employment.

JEL Classification: J24, L26, M13, Q33, Q35

Keywords: Entrepreneurship, Oil and Natural Gas, Hydraulic Fracturing, Incorporated Self-employment, Unincorporated Self-employment

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1 Introduction

Entrepreneurs, in particular small business owners, are commonly viewed as the engine of economic growth and prosperity. They play a disproportionately large role in job creation and destruction, and hold a substantial portion of the U.S. wealth. For instance, Fairlie et al. (2019) find that startups create approximately 3 million jobs per year with 2.9 million of these jobs persisting five years later. Perhaps most staggering, without these jobs, net job creation in the United States by all other businesses would be negative. Further, De Nardi et al. (2007) report that more than half of self-employed business owners fall in the top wealth quantile. Therefore, understanding the nature of entrepreneurship and identifying factors that affect it has always been of interest to governments, policymakers, and researchers.

Self-employment has been considered as the "simplest kind of entrepreneurship" (Blanchflower and Oswald, 1998), and a large body of research documents that individuals' decision to engage in entrepreneurship is impacted by economic conditions.[1] In this paper, we contribute to this literature by investigating how localized boom and bust cycles, induced by oil and gas activity, impacted self-employment in the U.S. over the past two decades. This time period provides a unique opportunity to study self-employment dynamics, as it was dominated by plausibly exogenous fluctuations in oil and gas activity due to the advent of production from shale geological formations. These "boom towns" experienced boom and bust cycles induced by a combination of external factors including oil and natural gas prices, resource availability, and differences in the oil to gas ratio of hydrocarbons produced that naturally varies spatially within individual basins and across basins. As a growing recent literature documents, these areas experienced employment growth throughout a broad group of sectors of the economy, even sectors not directly related to oil and gas activities. Although our analysis will focus on the entire U.S. (not just these shale areas), we will show that much of the fluctuation during the time frame of our analysis (2005-2019) was driven by these shale areas.

[1] Levine and Rubinstein (2018) refer to incorporated self-employment as a crude measure of entrepreneurship. Other studies identify entrepreneurship by the number of employer establishments (e.g., Haltiwanger et al. (2013)). But Fairlie (2014) point out that employer-based counts represent a small share of entrepreneurship. Individual business owners cover both employer and non-employer firms and hold at least 40 percent of total U.S. wealth (De Nardi et al. 2007).

Oil and gas activity can affect self-employment through different channels. Perhaps most directly, it may create new business opportunities in the mining sector and other industries that support the mining sector through input-output linkages. In addition, local landowners who receive bonus and royalty checks for oil and gas production that occurs beneath their land may use this capital to start their own business (Brown et al., 2019). This wealth shock could reduce liquidity constraints for entrepreneurs trying to start a business. On the other hand, though, a business cycle expansion can increase the opportunity cost of becoming self-employed due to an increase in market wages. Therefore the net impact of these oil & gas shocks on self-employment is a priori ambiguous, and addressing it is ultimately an empirical question.

We utilize data on self-employment from the U.S. Census American Community Surveys (ACS), and further distinguish between incorporated and unincorporated self-employed workers, as these have been shown to have starkly different traits and income profiles (Levine and Rubinstein, 2017). We aggregate self-employment to commuting zones (CZs), which represent clusters of counties that have strong commuting ties between workers and businesses (Tolbert and Sizer, 1996). To identify the causal effect of oil and gas activity on self-employment, we use detail well-level oil and natural gas production data for more than one million wells in the United States. For each county and month, we calculate the value of production from new wells (i.e., wells began production within the preceding 12 months). These monthly county values are then aggregated into yearly CZs.

Our main findings can be summarized as follows. First, we find that new oil and gas production has a positive and significant contemporaneous impact on self-employment, and the effect completely stems from the impact on unincorporated self-employment. A one-year lagged effect of the new value of oil & gas production on self-employment is negative. We interpret these results to suggest that unincorporated self-employment is procyclical. We do not find evidence of either pro- or counter-cyclicality of incorporated self-employment.

We next estimate the sensitivity of total employment to new oil and gas production and then decompose the share of the employment adjustment that stems from self-employment. Point estimates suggest that about 8-9% of the employment adjustment can be explained by unincorporated self-employed workers, a group which makes up less than 6% of total employment. Thus, these results broadly corroborate prior literature that finds that the entry margin accounts for an important share of a business cycle adjustment (Decker et al., 2014), although this literature has focused mainly on business establishments.

Finally, we also investigate the effects of self-employment within industries. Perhaps unsurprisingly, self-employment is found to be procyclical in the mining sector, but this sector makes up a relatively small share of the economy wide self-employment adjustment. About two thirds of the adjustment in self-employment comes from services sectors.

This paper first contributes to a large literature on self-employment. One strand of this literature focuses on the role of individual traits (e.g., attitudes toward risk, non-pecuniary benefits, etc.) that affect the choice to become self-employed (Chanda and Unel, 2021, Hurst and Pugsley, 2017, Levine and Rubinstein, 2017). A larger strand of the literature also examines how external factors such as access to credit (Asiedu et al., 2012, Cagetti and De Nardi, 2006, Hurst and Lusardi, 2004), inheritance and gift (Blanchflower and Oswald, 1998), globalization (Dinopoulos and Unel, 2015, Eren et al., 2019), immigration (Fairlie and Meyer, 2003, Kerr and Kerr, 2018), and government policies (Beland and Unel, 2019, Cullen and Gordon, 2007), among others. A few papers empirically explored self-employment throughout the economy wide business cycle (Fossen, 2020, Koellinger and Thurik, 2012, Levine and Rubinstein, 2018), and find mixed results on the cyclicality of self-employment.

This paper also contributes to a growing body of work that quantifies the economic effects of localized natural resource based booms.[2] While this literature began before the specific shale oil and gas booms of this past decade (Allcott and Keniston, 2018, Black et al., 2005), this new era of shale has created a significant resurgence in part because of the clean empirical identification afforded by the nature of the shock. Previous studies have investigated the impact of shale boom on various outcomes, including financial markets (Gilje, 2019, Plosser, 2015), consumer expenditure and debt (Brown, 2015), government spending (Bartik et al., 2019, Marchand and Weber, 2015), housing markets (Bartik et al., 2019, McCollum and Upton, 2018, Muehlenbachs et al., 2015), migration (Bartik et al., 2019, Cosgrove et al., 2015), birth and marriage decisions

[2]We are interested in short-term boom and busts induced by resource extraction, in contrast to the (very different) large literature on resource endowments and long run economic growth (Alexeev and Conrad, 2009, Michaels, 2010, Oliver and Upton, 2022, van der Ploeg, 2011, Venables, 2016).

(Kearney and Wilson, 2018), voting preferences (Fedaseyeu et al., 2015), among others. Our paper is more closely related to studies that have investigated the effects of resource booms on labor-market outcomes.

Agerton et al. (2017), Feyrer et al. (2017), Marchand (2012) find a positive effect of oil and gas activity on employment. Green et al. (2019) estimate that resource booms accounted for 49% of the wage growth in Canada between 2000 and 2012.[3] Using the Census Bureau's Longitudinal Business Database (LBD), Decker et al. (2021) show that the growth of aggregate employment in response to the shale boom is, on net, entirely accounted for by new firms and new establishments of existing firms. While positive effects associated with the economic activity spurred by drilling and production have been documented extensively, negative effects might also be observed, specifically in the manufacturing sector (Cosgrove et al., 2015, Freeman, 2009).

Our paper relates most closely to two recent studies at the intersection of oil & gas booms and entrepreneurship activity: Tsvetkova and Partridge (2017) and Bellon et al. (2021). The former examines the impact of employment growth in oil and gas industry on self-employment growth in the U.S. over the 2001-2013 period. They find that oil and gas sector expansion crowds out self-employment, which stems from a large reduction in self-employment in non-mining sectors. Our analysis differs from theirs in several aspects. Most notably, we use oil and gas production from *new* wells, which depends on preexisting geology and the recent drilling technology. Therefore, unlike employment growth, new production is plausibly exogenous to other shocks occurring in the region, and more appropriate for identification. Results of our analysis do not corroborate conclusions from theirs.

Using data on unexpected payments to individuals from the shale boom in Texas, Bellon et al. (2021) investigate the effect of wealth windfalls on self-employment decisions. They find that individuals who received large wealth shocks have higher self-employment rates relative to others who received smaller or no wealth shocks. Our study documents the net effect of the shale boom on entrepreneurship, and does not focus on individual decisions based on specific

[3]Other studies corroborate the positive impact of the shale boom on local labor markets (Bartik et al., 2019, Jacobsen, 2019, Komarek, 2016, Maniloff and Mastromonaco, 2017, Marchand and Weber, 2018, Weber, 2012). It should be noted that due to the oil and natural gas price declines of 2014, there is an emerging literature on the "bust" side of the cycle that will likely grow in upcoming years. For instance, Brown (2015) finds that elimination of each active rig eliminates 28 jobs in the first month and this increases to 171 jobs eliminated in the long-run.

royalty payments. We therefore view Bellon et al. (2021) as complementary to our work.

The rest of this paper is organized as follows. Section 2 introduces the data on labor markets and oil and gas production along with measurement and construction of key variables. Section 3 describes our estimation strategies. Section 4 presents our results and discuss their implications. Section 5 investigates the robustness of our findings, and Section 6 concludes the paper.

2 Data and Descriptive Statistics

This section discusses the sources and construction of key variables used in our analysis. We first discuss the data on labor markets, in particular, on self-employed individuals and their characteristics. We then introduce and discuss the data on oil and gas production.

2.1 Labor Market Data

Data on self-employment and wage workers are from the American Community Survey (ACS). We utilize publicly available data from the Integrated Public Use Micro Samples (IPUMS) website (Flood et al., 2020) for years 2005 to 2019. Microdata is acquired at the Public Use Microdata Area (PUMA) geographic granularity.[4] Counties are the smallest geographic unit identified in data files, however, due to small samples especially in rural counties, for approximately forty percent of individuals county identifiers are not available for disclosure reasons.[5]

Our analysis is at the Commuting Zone (CZ) level. We choose CZs as the level of geographic granularity as they represent clusters of counties with strong commuting ties between employers and employees as many workers commute across counties for work (Tolbert and Sizer, 1996). CZs therefore represent a more cohesive labor market than counties, and have been extensively used in recent research (Autor and Dorn 2013, Feyrer et al. 2017, Autor et al. 2019, among others). Using crosswalk files from Autor and Dorn (2013) and Autor et al. (2019), we map PUMAs to 741 commuting zones that cover the entire area of the U.S. over the period 2005–2019.[6] Utilizing CZs not only identifies a more cohesive labor market, but also circumvents

[4]2005 is the earliest year for which yearly data is continuously available at the PUMA level.

[5]Metropolitan statistical area (MSA) is another geographic unit identified in the ACS. However, like counties, many MSAs are incompletely identified, and using them does not cover the entire area of the U.S.

[6]Crosswalk files are available at David Dorn's website: https://www.ddorn.net/data.htm.

dropping the prior-mentioned forty percent of individuals with missing county identifiers. This is especially important in this context, as many shale counties are rural.

The ACS covers more than two million households per year, and provides information about demography (i.e., gender, age, race), educational level, work (i.e., employment status, worker class, industry worked, occupation, etc.), health insurance, and migration. Our analysis considers individuals 16 years and older who work in non-agricultural private sector, and we exclude all observations with imputed/missing employment status, worker class, and industry.

The survey classifies workers as self-employed or wage and salary workers, with the former further classified as incorporated and unincorporated. Incorporation occurs at the state level and therefore differs across states as such. Broadly speaking, incorporation involves creating a legal entity that is distinct from the owner. This allows the corporation to take out debts and be involved in legal disputes separate from its owner. Corporations are made up of shareholders and have the advantage of being able to more easily raise capital from outside investors. Corporations also typically have additional responsibilities such as being required to hold regular meetings and register with the Secretary of State in the state of incorporation ever year.[7]

Previous studies have broadly referred to all self-employed individuals as entrepreneurs (Blanchflower and Oswald, 1998, Borjas and Bronars, 1989, Fairlie, 2014). However, Levine and Rubinstein (2017) show that incorporated and unincorporated self-employed individuals differ in their cognitive and non-cognitive traits. For example, incorporated self-employed are more educated and earn more than salaried workers. By contrast, unincorporated self-employed individuals are generally in low-skill intensive occupations. While there are differences in nomenclature across the literature, we specifically examine self-employment, and further distinguish between incorporated and unincorporated self-employed workers. Given the nature of the shale boom shock which overwhelmingly directly impacted blue collar workers with high school education (Upton and Yu, 2021), distinguishing between incorporated and unincorporated self-

[7] An important distinction is between a corporation and limited liability company (LLC). Similar to corporations, LLCs also create separate legal entities from the owner that reduces liability and allows the LLC to take out debt separate from its owner. LLCs are not incorporated businesses, though. Furthermore, not all unincorporated businesses are LLCs. Thus, unincorporated businesses broadly fall into two categories; (1) limited liability companies that are distinct legal entitles from their owners and (2) sole-proprietorships or partnerships that are not legally distinct entities. Ideally, we would be able to differentiate incorporated businesses, LLCs, and other self-employment. But data is not available.

employment is particularly relevant.

Table 1 reports descriptive statistics on different classes of workers; numbers in parentheses are standard deviations. Column 1 in Table 1 presents the statistics related to all self-employed individuals, whereas columns 2 and 3 disaggregate self-employed workers as incorporated or unincorporated business owners, respectively. The last column reports the corresponding statistics for wage and salary workers. The sample covers about 16.9 million observations, 9.4 percent of which is self-employed (see the last row). Columns 1-3 reveal that white and male workers are a higher proportion of self-employed compared to wage workers.

Summary statistics show that incorporated and unincorporated self-employed workers differ in a few important ways. While incorporated self-employed workers work more than wage and salary workers, unincorporated self-employed workers work fewer hours. Further, the average annual earned income of incorporated self-employed workers is about 40 percent higher than wage workers, and is 61 percent higher than unincorporated self-employed. Thus, consistent with Levine and Rubinstein (2017), these summary statistics show that incorporated self-employed individuals are more educated, work longer hours, and have higher annual income than unincorporated self-employed and wage workers.[8] Both incorporated and unincorporated self-employed workers represent higher shares in the construction and service sectors and lower shares in mining, manufacturing and transportation.

Figure 1 shows time trends of self-employed individuals as a percent of total employment in our sample. The share of self-employed individuals is about 10 percent in 2005, and declines to about 8.3 percent by 2013, remaining relatively constant thereafter. Note that the share of incorporated and unincorporated self-employed individuals follow a similar pattern. The time trend of each group, however, vary substantially across commuting zones.

2.2 Oil and Gas Data

We utilize detailed well-level production estimates for more than one million wells in the United States as compiled by Enverus (formerly DrillingInfo). Enverus collects data from state agencies

[8]Numbers reported in Table 1 are in thousands of 2015 dollars, using the CPI retrieved from FRED, Federal Reserve Bank of St. Louis. The bottom 1 percent and the top 1 percent of income data are trimmed from the sample.

such as the Railroad Commission of Texas, the Department of Natural Resources in Louisiana, and North Dakota Industrial Commission. In different states, oil and gas production is reported at different levels of aggregation, which typically include leases, units, or wells.[9] *Enverus* compiles the data across states and calculates well-level monthly production estimates of oil and natural gas.

As an identification strategy, we will utilize the timing and intensity of oil and gas activity alongside geological data on reservoirs thousands of feet below the earth's surface. To measure the timing and intensity of the shale boom, for each month, oil and natural gas production from all wells that began production within the past 12 months across county equivalents in the United States is summed. We then multiply oil and natural gas production by West Texas Intermediate oil price and Henry Hub natural gas price sourced from the U.S. Energy Information Administration (EIA) to calculate the estimated total value of oil and gas production from new wells in each county.[10] These county estimates are then aggregated into Commuting Zones.[11] All values are expressed in 2015 millions of dollars using the CPI.[12]

Figure 2 illustrates the variation in timing of the booms and busts of between the seven largest shale areas in the U.S. across a number of dimensions.[13] First, Figure 2a shows that the seven largest shale plays are geographically dispersed throughout the country. The placement of these areas is determined by geological formations thousands of feet below the earth's surface. Naturally, each of these formations has different compositions of oil and natural gas. For example, the Haynesville and Appalacia areas are overwhelmingly "dry" natural gas, as opposed to Bakken which is overwhelmingly oil. Eagle Ford has a mix of both oil and natural gas, and the

[9] Unitization is when several tracts of land with different ownership are pooled together for purposes of sharing royalties. For instance, a company cannot typically drill on a one acre plot of land and associate all of the production to the surface land owner, as the oil and natural gas is being pulled from adjacent land with different owners. Individual states have different processes for addressing this common issue. A detailed description of the laws surrounding oil and gas drilling with a focused comparison between Louisiana and Texas can be found in (Martin and Yeates, 1992).

[10] Agerton and Upton (2019) show that oil prices vary significantly across locations, especially during the peak of the shale boom. During the time of this writing, similar large wellhead price discounts are observed in natural gas markets. In this way, the value of production is likely over-stated and therefore point estimates are likely understated.

[11] In this aggregation process, we use crosswalk files at Dorn's website: https://www.ddorn.net/data.htm

[12] CPI retrieved from FRED, Federal Reserve Bank of St. Louis: https://fred.stlouisfed.org/series/CPI.

[13] These shale plays are from the U.S. geological survey (EIA, 2011). For illustrative purposes we utilize the seven geographic areas highlighted in the U.S. Energy Information Administration's Drilling Productivity Reports.

ratio of oil and natural gas naturally changes geographically across the play.

Next, Figure 2b shows the variation in the timing of oil and natural gas price changes. In the early part of the sample, oil and natural gas prices move in tandem with one another.[14] But in 2009, the price of oil and natural gas began to diverge. This divergence continued until 2014, when prices converged once again with the oil price drop. The timing of oil and natural gas price shocks impacted different plays in very different ways. As shown in Figure 2c, in the early sample period, the Haynesville shale accounted for a relatively large share of value of new production, but by 2014 this had attenuated significantly. Compare this to Bakken that had a small share of value of new production at the beginning of the sample, and this peaked in 2013 before the oil price crash in 2014.

Finally, Figure 2d shows the value of production from new wells (inclusive of oil and natural gas) in these largest seven shale plays compared to all other counties in the United States. This figure illustrates that the value of production in the early sample period for shale and non-shale regions were approximately parallel. But beginning around 2009, the two diverge considerably, with the lion's share of value of new production coming from shale counties. The 2014 price bust is observed and then a rebound through 2019. Altogether, Figure 2 illustrates the spatial and temporal variation that will be utilized in identifying the effect of oil and gas induced localized business cycles on self-employment.

3 Empirical Methodology

To estimate the impact of oil and gas extraction on decision to become self-employed, we first introduce some notation. Let E_{zt} denote the number of self-employed individuals owning businesses in the non-agricultural private sector in commuting zone (CZ) z in year t. If we consider a particular type of self-employment, say incorporated, E_{zt} denotes the number of incorporated self-employed business owners.[15] Let NV_{zt} denote the total market value of oil and gas produc-

[14] Historically, oil and natural gas prices moved in tandem.

[15] For each CZ and year, we calculate E_{zt} by multiplying the share of self-employment in CZ total employment (calculated from the ACS data) with the CZ employment numbers (from the Bureau of Labor Statistics). The latter data are available at the county-level since 1990, and we aggregated these counties into CZs using Dorn's crosswalk file.

tion (in 2015 millions of US$) from new wells in the commuting zone normalized by the 2005 CZ employment.[16]

We then estimate the following model

$$\triangle E_{zt} = \beta \text{NV}_{zt} + \beta_1 \text{NV}_{z,t-1} + \eta_z + \eta_t + \varepsilon_{zt}, \tag{1}$$

where $\triangle E_{zt} = (E_{zt} - E_{z,t-1})/L_{z,2005}$, i.e. the net change in the number of self-employment normalized by the 2005 CZ employment.[17] We include $NV_{z,t-1}$ to control for the dynamic effects of oil and gas production.[18] The coefficient β measures the contemporaneous effects of new production. This specification allows for simple interpretation, namely, one billion dollars of production increases the number of business owners by 1,000 $\times$ β.

If $\beta > 0$ and $\beta_1 < 0$, this will provide evidence that self-employment is procyclical, as oil and gas activity has a contemporaneous positive effect on self-employment with self-employment reducing once the new activity subsides. In contrast, if $\beta < 0$ and $\beta_1 > 0$, this will provide evidence that self-employment is countercyclical, as oil and gas activity has a contemporaneous negative effect on self-employment.

CZ fixed effects η_z are included to control for time-invariant factors that can affect entrepreneurship dynamics across commuting zones, and time fixed effects η_t to control for common macroeconomics shocks and trends. Finally, ε_{zt} is the error term, and we report heteroskedasticity robust standard errors clustered at the CZ-level.[19]

We will also estimate equation equation (1) utilizing total employment (in lieu of self-employment). Although point estimates for β and β_1 will be presented, the focus of the analysis is the share of the total employment effect that can be explained by self-employed workers. We

[16] The normalization is done to control for the cross-zone differences in population. We chose the 2005 CZ employment (instead of the previous year's employment) to reduce concerns that population grew due to the shale boom. However, we later show robustness checks where we normalize by the previous year's employment.

[17] Note that $\triangle E_{zt} = \triangle E^i_{zt} + \triangle E^u_{zt}$, where indexes i and u denote incorporated and unincorporated, respectively. Thus the impact of oil and gas production on all self-employment is the sum of the effects on incorporated and unincorporated self-employment, i.e., $\hat{\beta} = \hat{\beta}^i + \hat{\beta}^u$. Indeed, this is true for any partition of any type of self-employment. In the next section, we partition our sample into industries.

[18] As will be shown in robustness checks, including further lags does not meaningfully impact results and coefficients on further lags are insignificant.

[19] Equation (1) does not include any CZ-level controls (e.g., proportion of the CZ labor force who are male, white, proportion of the labor force with some college education, etc.). These are potentially outcome variables, and considered bad controls (Angrist and Pischke, 2009). However, including them in the model does not have significant effects on estimates, as we shall show later.

heed caution in the interpretation of β and β_1, as the value of production (see Section 2.2) is based on prices of oil and natural gas at trading hubs. Thus, the actual value of production in the specific location is likely less, therefore β and β_1 are overestimated relative to the value at the wellhead.

4 Results

This section presents the results of our empirical analysis. We first report and discuss results based on equation (1). We then conduct our analysis at industry level. Finally, we conduct robustness checks by investigating the sensitivity of results to the the inclusion of additional control variables, sub-samples of the data, inclusion of further lagged independent variables, among others.

4.1 Main Results

Table 2 reports the impact of new oil and gas production on the change in self-employment using equation (1). Here "All" represent total self-employment (i.e., both incorporated and unincorporated). The sample size in each column is 10,374 observations from 741 commuting zones over the 2006–2019 period. All regressions include commuting zone and year fixed effects, and numbers in parentheses are robust standard errors clustered at the CZ-level. Regressions are weighted by the 2005 CZ employment to generate population relevant estimates.

Point estimates in Column 1 of Panel A suggest that one billion dollars of oil and gas production from new wells is associated with 73 new self employed workers contemporaneously. The coefficient on lagged new production (NV_{t-1}) suggests a reduction of 52 self-employed workers. Columns 2 and 3 consider incorporated and unincorporated self employment separately. Point estimates for incorporated are small and statistically insignificant, with both contemporaneous and lagged effects on self-employment in column 1 being driven by unincorporated self-employment. Point estimates suggest that a one billion dollars of new oil and gas production is associated with a contemporaneous increase in 61 new unincorporated individuals. However, in the year after the shock, the point estimate implies a reduction of 52 unincorporated self-employed workers. A joint test of significance for the contemporaneous and lagged effect yields a statistically insignificant increase in nine unincorporated self-employed individuals.[20]

Next, we consider whether effects on self-employment can be explained by the mining sector. To address this, in columns 4-6 of Table 2, we estimate the effect on all industries excluding mining. Results in column (6), that exclude the mining sector, suggest that one billion dollars of new oil and gas production is associated with a contemporaneous increase in 57 new unincorporated workers, and a lagged reduction of 43 unincorporated workers the following year. Thus, these results suggest that self employment adjustments are mainly coming from sectors outside of mining sector. In sum, Table 2 broadly finds evidence of a contemporaneous increase in unincorporated self-employment associated with oil and gas booms, but in the next period (absent an additional shock), the labor markets adjusts approximately back to pre-boom levels. The vast majority of the effects are coming from non-mining industries.

4.2 Self-employment's Share of Employment Fluctuations

We now turn to evaluate the role that self-employment played in the overall employment adjustment. Columns 1-3 of Table 3 present the benchmark result from Table 2, and column 4 reports the estimated effect on total employment (inclusive of self-employment and wage & salaried workers). Focusing on column 4, we find that one billion dollars of new oil and gas production is associated with a contemporaneous increase in about 770 new jobs. Viewing the lagged coefficient, the point estimate implies a reduction in 560 jobs the following year. A joint test of significance for the sum of the contemporaneous and lagged effect yields a statistically significant increase in 210 new jobs.

Panel B calculates the share of the total employment adjustment that stems from self-employment. We find that between 7.9% and 9.3% of the total employment adjustment comes from unincorporated self employed workers, a group that makes up around 5.9% of employment over our sample period.[21] Thus, we find empirical evidence that (1) self-employment is procycli-

[20]One plausible explanation for the short-term impact on unincorporated self-employment is that while the production from an oil and/or gas well can continue for decades once drilled, wells typically experience a relatively quick decline from the initial production levels; this is especially true in shale formations. Newell et al. (2016), for example, show that one year after the start of production the median well is producing about 40 percent of the initial peak.

[21]Compare Panel C to summary statistics presented in Table 1.

cal, (2) this procyclicality is explained by unincorporated self-employed workers, and (3) that self-employment makes up an economically meaningful share of the employment adjustment.

Several studies have investigated the cyclicality of self-employment, and results are mixed (Blanchflower, 2000, Fossen, 2020, Koellinger and Thurik, 2012, Levine and Rubinstein, 2018, Lin et al., 2000). Notably, and in contrast to our analysis, these studies investigate the cyclicality of self-employment throughout the economy-wide business cycles. For example, utilizing panel data from 22 OECD countries, Koellinger and Thurik (2012) find that GDP and unemployment cycles do not predict the entrepreneurial cycle. However, Levine and Rubinstein (2018), using individual-level data from the NLSY79, show that the *likelihood* of becoming incorporated (unincorporated) self-employed is negatively (positively) correlated with the state unemployment rate, and conclude that incorporated self-employment is procyclical, unincorporated self-employment countercyclical, and aggregate self-employment countercyclical. This phenomenon is explained if individuals are more likely to become self-employed because they cannot find suitable jobs during a recession and/or less likely to become self employed during an expansion because better paid jobs are available through employers. Our analysis, however, explores the cyclicality of self-employment by exploiting shocks in the value of oil and gas production in local economies. Results suggest that in net, self-employment is pro-cyclical in the local areas that experienced oil and gas activity.

Also notably, the implied definition of procyclical versus countercyclical differs across studies. While this might appear to be nuanced, the differences are important when compiling a synopsis of the literature or comparing results across studies. In this analysis, we examine the level of self-employment throughout the local boom/bust cycle, finding that both total employment and self-employment increase during the boom and decrease during the bust. More specifically, as stated in Section 3, we find that $\beta > 0$ and $\beta_1 < 0$, thus providing evidence that self-employment is procyclical, as oil and gas activity has a contemporaneous positive effect on self-employment with self-employment reducing once the new activity subsides. But other analyses of self-employment consider the *share* of total employment that is self-employed or the *probability* of a worker being self-employed throughout the business cycle. These analyses therefore take into account both the level of self-employment but also the total economy employment or labor supply. It possible that the share of self-employed workers does not change (or even declines) during a labor market expansion, yet the total number of self-employed workers increases.[22]

4.3 Industry-Level Analysis

In this section we further investigate differential effects on self-employment across industries. We divide our sample into five broad industries: mining, construction, transportation, manufacturing, and other services. Using equation (1), we separately estimate the impact of new production on self-employment in each industry. Results are given in Table 4. As in Table 2, all estimates include CZ and year fixed effects and standard errors are clustered at the CZ-level, and observations are weighted by the 2005 CZ employment.

For comparison, Panel A reproduces the results in columns 1-3 of Table 2. Note that the sum of self-employed individuals across industries in each commuting zone gives the total self-employment there, i.e. $\triangle E_{zt} = \sum_k \triangle E_{zt}^k$ where k indexes industry. It then follows from equation (1) that the sum of estimated coefficients on NV_t (or NV_{t-1}) across industries for any type of self-employment equals the corresponding point estimate on NV_t (NV_{t-1}) in Panel A.

As noted in the previous section, the impact of new oil and gas production on self-employment in mining sector is small; one billion dollars of production from new wells is associated with an increase in 6 self-employed workers (Panel B in Table 4). As shown in Panels C–E, the contemporaneous shock has a small and mostly insignificant impact on self-employment in the construction, transport and manufacturing sectors. Panel F of Table 4 shows that the impact on unincorporated self-employment mainly stems from the "Other Services" sector. Specifically, one billion dollars of new production is associated with a contemporaneous increase in 41 new unincorporated business owners, and a lagged reduction of 36. The net effect after a one period shock is five workers, but this is not statistically significantly different than zero.

We further disaggregate "Other Services" sector into four sub-sectors: wholesale and retail trade, business and repair services, personal and entertainment services, and professional services.[23] Our analysis shows that for unincorporated self-employment, the signs of estimated

[22] Our estimates, for example, imply that the self-employment share in total employment increases slightly.

[23] Professional services include education, finance, health, utilities, and other professional services.

coefficients in each industry are the same as those in Panel E (see Table A1 in the appendix). Results reported in this table indicate that effects are more substantially observed in Personal and Professional Services.

4.4 Discussion

There are two direct channels through which an oil and gas boom can stimulate a local economy. First, local landowners receive bonus and royalty checks for oil and gas production that occurs beneath their land. A bonus check is given to the landowner at the time that a lease is signed as a lump sum payment. But also, once production begins landowners receive royalty payments that is some share of the value of the oil and gas produced (typically 20-25%).[24] These royalty payments might only continue for a short time if the well is relatively unsuccessful, or can continue for years and even decades as the well continues along its tail of production. Thus, when local residents receive payments this might provide resources needed to start a business. For perspective, Brown et al. (2016) estimate that six major shale plays generated $39 billion in private royalties in 2014. This mechanism is explored in Bellon et al. (2021) who find that individuals who receive wealth shocks of $50,000 or greater have about 60% greater self-employment rate relative to individuals who receive small or no wealth shocks. In the context of self employment, these royalty payments might reduce liquidity constraints and spur entrepreneurship (Levine and Rubinstein, 2018).

The second direct channel through which oil and gas operators can stimulate a local economy is through the broader economic activity generated. First, when landowners receive bonus and royalty payments, they will likely spend some share of these in the local economy, providing stimulus. But second, the drilling activities themselves will also boost employment and earnings. In the case of the shale plays, the operator (i.e. the company responsible for planning and eventually running the day-to-day operations of the well) typically contracts out a service company to both drill the well and complete the hydraulic fracturing needed to stimulate the well to begin production. These workers will earn income directly, and then spend some share

[24] The surface owner of the land where the actual well is drilled typically receives a "rental" payment that is the value of renting the surface area needed to drill and produce. Most landowners, though, receive a bonus and royalty payments even though no actually drilling activity occurred on their land.

of these earnings in the local economy. As previously discussed, employment and earnings have been found to increase across all sectors of the economy in shale boom areas.

We are unable to distinguish between these two channels, and both channels could impact self-employment across sectors. This is a general limitation of the broader literature focusing on the economic implications of localized oil and gas activity.

5 Robustness

In this section, we present sensitivity checks to investigate the robustness of our finding to additional controls, spatial spillovers, migration, among others. Robustness checks to our main specification are presented in Table 5, and results from industry-level analyses are reported in Appendix Tables A2–A6.

Log of New Production

In our data, the majority of CZs do not have any oil and gas activities, and thus the production data are right skewed. One simple way to address this issue is to replace NV_{zt} and NV_{zt-1} with $\ln(NV_{zt} + 1)$ and $\ln(NV_{zt-1} + 1)$, respectively, in equation (1). We do not take logs of the dependent variable because it can be negative. The estimated coefficient measures the semi-elasticity: how much self-employment changes with respect to a one-percent increase in oil and gas production. Panel A of Table 5 reports results based on this specification, and note that they are qualitatively similar to those reported in Table 2.

We also estimate the role that self-employment played in the overall employment adjustment. Estimated coefficients on $\ln(NV_{zt} + 1)$ and $\ln(NV_{zt-1} + 1)$ when the dependent variable is employment change are 1.226 (0.362) and -0.886 (0.210), respectively; as a result, between 8.6% and 9.9% of the total employment adjustment comes from unincorporated self-employed individuals, which are very comparable to those reported in Table 3.

Additional Controls

Panel B of Table 5 reports results with additional CZ-level time varying controls included in our specification shown in equation (1). The set of controls includes the start-of-year share of a CZ's labor force who are male, the share of CZ population that is white, proportion of the population in prime-age (25-54 years old), proportion of the population with some college education or more, and the share of population that is immigrant. As mentioned earlier, these are not included in the main specification because they are potentially endogenous variables. Their inclusion, however, does not have a meaningful impact on estimates. Of the six coefficients presented, none are statistically significantly different than the benchmark result presented in Panel A.

Spatial Spillovers

We test the sensitivity of our results to potential spatial spillovers. Specifically, CZs that are in states with shale activity but that themselves do not overlap with EIA's seven major shale plays highlighted in the *Drilling Productivity Reports* are removed from the sample. In addition states that directly border counties with shale activity were removed.[25] Prior analyses have also found that significant midstream and downstream investments occurred in response to the shale boom. For instance, Dismukes and Upton (2020) estimates that over $110 billion in refining and chemical manufacturing investment occurred in Texas and Louisiana during the shale boom, but is mostly located near the Gulf Coast, not in the areas where the shale production actually occurred. Further, connecting this upstream production with refineries and chemical plants spurred significant investment in transportation infrastructure (Agerton and Upton, 2019, Agerton et al., 2020).

Because these spatial spillovers created similar "boom town" effects in areas without shale production, inclusion of these ares has the potential to bias point estimates downward. For example, Lake Charles Louisiana was the fastest employment growth MSA in the country from 2013-2018, and had no shale activity. But, the MSA underwent billions of dollars of capital expenditure, in chemical manufacturing and the export of natural gas in the form of liquefied natural gas (LNG) that was made possible by oil and gas extraction growth in shale regions (Scott and Upton, 2019). Of the six coefficients presented in Panel C, none are statistically

[25] After applying these criteria, the following non-shale boom states are included: AK, AZ, CA, CT, DE, FL, GA, HI, ID, IL, IA, ME, MI, MN, MS, MO, NV, NH, NJ, NC, OR, RI, SC, TN, VT, WA, and WI. For a more detailed description see McCollum and Upton (2018), Decker et al. (2021) and Upton and Yu (2021).

significantly different than the benchmark result presented in Panel A.

Labor Migration

Areas experiencing economic boom generally induce in-migration, which naturally changes population level and demographic composition. Self-employment changes can come from both self-employed workers migrating into and out of boom areas, or due to individuals living in these areas becoming self employed. This is perhaps one way in which a regional boom bust cycle can differ from a nation-wide business cycle, as discussed in Section 4.2. To partially address this in our main specification, we consider the change in self-employment (instead of self-employment level) normalized by the labor-market size in the prior period (see equation 1).

We next conduct an additional robustness check dropping recent movers from the sample. The American Community Survey (ACS) is a repeated cross sample and therefore we cannot track individuals over time. However, the ACS ask individuals whether they had lived in the "same house" or a "different house" one year earlier. Those who had moved indicate whether they moved within state, between states, or were abroad one year ago. To again partially address the question of migration, we investigate how the new oil and gas production has affected self-employment among non-movers, and the results are reported in Panel D Table 5. Point estimates are similar to those in the benchmark results in Panel A, with magnitudes unsurprisingly on average smaller (as there are less individuals in the sample), suggesting that effects are not driven by migration. Again, none of the six coefficient estimate are statistically significantly different than the benchmark result.

Population Trends

As discussed in Section 3 the dependent variable of interest in the change in employment normalized to the employment in each CZ in 2005, defined as $\triangle E_{zt} = (E_{zt} - E_{z,t-1})/L_{z,2005}$. We choose to normalize by 2005 employment, as labor migration can cause population to increase in response to the boom. As an additional robustness, we normalize the change in employment to the employment in the prior year, $\triangle E_{zt} = (E_{zt} - E_{z,t-1})/E_{z,t-1}$. This is consistent with the approach used in Feyrer et al. (2017). Results shown in Panel E remain qualitatively similar to those in the benchmark case, although coefficient estimate are smaller in magnitude in five of the six coefficients, and statistical significant attenuates generally.

IV Estimates

The availability of a resource is clearly exogenous. However, one may argue that a firm's decision to extract in a particular location may not be. To address potentially confounding effects and capture variation both across time and across shale plays, we use the instrumental variable (IV) approach proposed by Feyrer et al. (2017). The goal of the instrument is to model the intensity of activity by examining the value of new production in a county such that intensity of activity varies across time and across the shale plays.

We estimate

$$\ln(\mathrm{NV}_{ct} + 1) = \alpha_c + \lambda_{st} + \nu_{ct}, \tag{2}$$

where NV_{ct} denotes the market value of new oil and gas production in county c and year t. Here, α_c is a dummy for each county, λ_{st} represents a set of dummies for each shale play-year combination, and ν_{ct} is error term. Adding these predicted values across counties in each commuting zone, we obtain predicted values for the new production in the CZ ($\widehat{NV}_{zt}$). Dividing it by the 2005 CZ employment, we use $\widehat{NV}_{zt}$ as an instrument for the oil and gas production NV_{zt} in equation (1). Similarly, we use $\widehat{NV}_{zt}$ as an instrument for NV_{zt-1}.

Panel F in Table 5 reports the results. The first-stage (Kleibergen-Paap) F-statistics is 9.58, which slightly lower than the conventional cutoff level of 10. Consistent with the benchmark results, estimates for total self-employment are statistically significant and mainly driven by unincorporated self-employed workers. But effects are about twice as large as the benchmark results (cf. Table 2). The estimates in the last column indicate that unincorporated self-employment is procyclical: one billion dollars of oil and gas is associated with an increase of 114 unincorporated self-employed workers, with a lagged reduction in 91 unincorporated self-employed workers. The combined effect is statistically insignificant.

Lags and Leads

The next two robustness checks include further lags and leads of the independent variable. In equation (1), to control for the dynamic effects we include one-year lagged value of new oil and gas production. Panel G of Table 5 reports results when we also include two-year lagged value of new production. Observe that for all three estimates, the sum of the two lagged values of production are equal to the first lag in the benchmark result. We therefore do not explore dynamics further.

We next perform a falsification test by including a lead value of production. The value of production in $t + 1$ should not have an impact on self-employment in year t. Panel H reports the results from this exercise, and note that estimated coefficients on the lead value is not only insignificant, but also small in magnitude.

The Great Recession

As a final robustness check, we test the sensitivity of our results to considering the effect of the Great Recession. During the Great Recession national unemployment increased sharply, investment fell substantially, and many businesses exited the market (Christiano et al., 2015). It was particularly hard for small businesses because financial institutions generally consider small business lending riskier than larger firms (Duygan-Bump et al., 2014). As shown in Figure 1, both incorporated and unincorporated self-employment rates declined during the Great Recession.

Prior literature documenting labor market effects of the shale boom have largely focused on the initial shale boom coinciding with the Great Recession.[26] While these results are notable in their own right, this timing generally calls into question the applicability of results in calibrating models to understand relationships during more "normal" times. For instance, the national unemployment rate peaked at 10 percent during 2009, coinciding almost exactly with when U.S. oil production began to increase from its almost 40 year trough in 2008. Following a recession, the aggregate labor market is slack, and therefore had this shock occurred at a time with a

[26]For instance, even the more recent studies Bartik et al. (2019), Feyrer et al. (2017), Tsvetkova and Partridge (2017) utilize data until 2014 at the latest.

tighter labor market, magnitudes of impacts across outcomes might be very different.

To examine the impact during the Great Recession, we interact the value of production with an indicator variable (denoted R for *recession*) that equals one for 2009-2011, and zero otherwise.[27] These results are presented in Table 6. For easy comparison, the benchmark result from Table 2 is presented in columns 1-3 with results including recession interaction effects in columns 4-6. All coefficients for recession interactions are imprecisely estimated, and the main conclusion is largely unchanged. Thus, results of this robustness check suggest that the benchmark result is not driven by the recession time period.

6 Conclusion

The U.S. shale boom has given rise to a large literature studying the economic effects of natural resource shocks. Although the literature has extensively investigated the effects on labor markets, limited attention has paid to how this revolution has affected entrepreneurship. Taking advantage of these plausibly exogenous shocks to local labor markets, we present empirical evidence that self-employment increases in response to oil and gas activity. Specifically, we find that (1) self-employment is procyclical, (2) this procyclicality is explained by unincorporated self-employed workers (in lieu of incorporated self-employed workers), and (3) that self-employment makes up an economically meaningful share of the employment adjustment. Point estimates suggest that between 7.9% and 9.3% of the total employment adjustment comes from unincorporated self employed workers, a group that makes up around 5.9% of employment over our sample period. Further, the industry-level analysis shows that around two thirds of the adjustment in self-employment comes from service sectors.

[27] NBER classifies the business cycle peak to trough as December 2007 and June 2009, respectively. Labor markets, however, had not recovered until 2012. For instance, in 2011, the unemployment rate was more than 8 percent. Since equation (1) includes NV_{t-1}, the period 2009–2011 includes the first year of recession (i.e., 2008).

Table 1: Summary Statistics on Worker Class, 2005–2019

	Self-employed Individuals			Wage
	All	Incorp.	Unincorp.	Workers
	1	2	3	4
Female (%)	36.9	30.0	41.0	49.1
Age	45.8	46.8	45.1	39.7
	(11.0)	(10.3)	(11.4)	(12.7)
White (%)	81.7	83.7	80.4	75.4
Some College (%)	64.7	73.6	59.5	64.5
Hours Worked	40.5	44.7	37.9	39.4
	(15.7)	(14.3)	(15.9)	(11.2)
Annual Income (1,000)	50.7	66.9	41.1	46.4
	(60.3)	(63.9)	(55.8)	(40.9)
Mining (%)	0.2	0.3	0.2	0.6
Construction (%)	18.2	16.8	19.0	6.2
Manufacturing (%)	4.1	5.5	3.3	12.8
Transport (%)	4.8	4.6	4.9	4.7
Service (%)	72.7	72.8	72.6	75.6
Sample Share (%)	9.4	3.5	5.9	90.6

Notes: The data draw on the ACS Files from IPUMS (Flood et al. 2020), and cover all individuals who are 16 years or older and working in the non-agricultural private sector. Some College represents all individuals who have at least some college education. The average annual income are in thousands of the 2015 US dollars. Numbers in parentheses are standard deviations, and the census weights are used in all calculations. Sample includes about 16.9 million observations.

Table 2: Impact of New Oil & Gas Production on Self-employment in the U.S.

	All Industries			Excluding Mining		
	All	Incorp	Unincorp	All	Incorp	Unincorp
Variable	1	2	3	4	5	6
NV_t	0.073***	0.012	0.061***	0.066**	0.010	0.057***
	(0.027)	(0.011)	(0.022)	(0.026)	(0.011)	(0.022)
NV_{t-1}	−0.052**	−0.000	−0.052***	−0.043**	−0.000	−0.043**
	(0.021)	(0.009)	(0.018)	(0.020)	(0.009)	(0.018)

Notes: The sample size in each panel is 10,374 observations from 741 U.S. commuting zones over the 2006–2019 period (includes 2005 with lagged value). All regressions include CZ-fixed and year-fixed effects and observations are weighted by 2005 CZ employment. Standard errors clustered at the CZ-level, and ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Table 3: Self-Employment as Share of Labor Market Adjustment

	All	Incorp	Unincorp	Employment
Variable	1	2	3	4
A. Estimates				
NV_t	0.073***	0.012	0.061***	0.770***
	(0.027)	(0.011)	(0.022)	(0.204)
NV_{t-1}	−0.052**	−0.000	−0.052**	−0.560***
	(0.021)	(0.009)	(0.018)	(0.119)
B. Share of Employment Adjustment				
NV_t	9.5%	1.6%	7.9%	
NV_{t-1}	9.3%	0.0%	9.3%	
C. Share of Aggregate Employment				
	9.4%	3.5%	5.9%	

Notes: The first three columns in Panel A represents the benchmark results from Table 2. Column 4 uses the total employment as the dependent variable, including self-employment and wage workers. All regressions include CZ-fixed and year-fixed effects and observations are weighted by 2005 CZ employment. Standard errors clustered at the CZ-level, and ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Table 4: Impact of New Oil & Gas Production on Self-employment by Industry

Variable	All 1	Incorp 2	Unincorp 3	All 4	Incorp 5	Unincorp 6
	A. All			B. Mining		
NV_t	0.073***	0.012	0.061***	0.006**	0.002	0.005**
	(0.027)	(0.011)	(0.022)	(0.003)	(0.002)	(0.002)
NV_{t-1}	−0.052**	−0.000	−0.052***	−0.009**	−0.000	−0.009**
	(0.021)	(0.009)	(0.018)	(0.004)	(0.002)	(0.004)
	C. Construction			D. Transport		
NV_t	0.001	−0.003	0.004	0.007	0.001	0.006*
	(0.013)	(0.004)	(0.010)	(0.005)	(0.003)	(0.004)
NV_{t-1}	0.007	0.005	0.002	−0.008*	−0.002	−0.006
	(0.014)	(0.005)	(0.010)	(0.005)	(0.004)	(0.004)
	E. Manufacturing			F. Other Services		
NV_t	0.007	0.003	0.003	0.049***	0.007	0.041***
	(0.007)	(0.003)	(0.004)	(0.017)	(0.007)	(0.014)
NV_{t-1}	−0.010	−0.005	−0.005	−0.032**	0.004	−0.036**
	(0.010)	(0.005)	(0.006)	(0.016)	(0.008)	(0.015)

Notes: The sample size in each panel is 10,374 observations. All regressions include CZ-fixed and year-fixed effects and observations are weighted by 2005 CZ employment. Industry aggregations based on 1990 Census Bureau industry classification system as reported in IPUMS-CPS. Other services includes wholesale and retail trade, finance and insurance, business and repair services, personal services, entertainment and recreation services, and professional and related services. Standard errors clustered at the CZ-level, and ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Table 5: Impact of New Oil & Gas Production on Self-employment: Robustness

Variable	All 1	Incorp 2	Unincorp 3	All 4	Incorp 5	Unincorp 6
	A. Log New Values			B. More Controls		
NV_t	0.121**	0.016	0.105***	0.073***	0.011	0.062***
	(0.048)	(0.020)	(0.036)	(0.028)	(0.011)	(0.022)
NV_{t-1}	−0.087**	0.000	−0.088***	−0.051**	0.000	−0.051***
	(0.036)	(0.015)	(0.030)	(0.021)	(0.010)	(0.018)
	C. Spatial Spillovers			D. Controlling Migration		
NV_t	0.057***	0.007	0.050***	0.065***	0.009	0.056***
	(0.016)	(0.010)	(0.015)	(0.023)	(0.010)	(0.018)
NV_{t-1}	−0.048***	−0.001	−0.047***	−0.048***	−0.001	−0.046***
	(0.018)	(0.009)	(0.016)	(0.018)	(0.008)	(0.014)
	E. Population Trends			F. IV Estimates		
NV_t	0.065*	0.008	0.058**	0.133**	0.019	0.114***
	(0.038)	(0.016)	(0.026)	(0.034)	(0.028)	(0.037)
NV_{t-1}	−0.015	0.013	−0.028*	−0.097*	−0.005	−0.091**
	(0.019)	(0.010)	(0.015)	(0.032)	(0.017)	(0.032)
	G. Further Lags			H. Leads		
NV_{t+1}				−0.006	0.004	−0.010
				(0.021)	(0.011)	(0.016)
NV_t	0.065*	0.003	0.061**	0.078*	0.008	0.070**
	(0.035)	(0.015)	(0.026)	(0.044)	(0.021)	(0.036)
NV_{t-1}	−0.030	0.023	−0.053*	−0.066***	−0.005	−0.062***
	(0.043)	(0.018)	(0.031)	(0.024)	(0.013)	(0.022)
NV_{t-2}	−0.022	−0.023*	0.001			
	(0.029)	(0.013)	(0.019)			

Notes: The sample size is 6,160 observations in Panel C and 10,374 in all other panels. All regressions include CZ-fixed and year-fixed effects and observations are weighted by 2005 CZ employment. Standard errors clustered at the CZ-level, and ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Table 6: Impact of New Production on Self-employment - Great Recession Robustness

	Benchmark Results			Impact of Recession		
	All	Incorp	Unincorp	All	Incorp	Unincorp
Variable	1	2	3	4	5	6
NV_t	0.073***	0.012	0.061***	0.069***	0.014	0.055***
	(0.027)	(0.011)	(0.022)	(0.025)	(0.012)	(0.020)
$R\times$ NV_t				0.060	−0.022	0.082
				(0.087)	(0.042)	(0.077)
NV_{t-1}	−0.052**	−0.000	−0.052***	−0.048**	−0.001	−0.047***
	(0.021)	(0.009)	(0.018)	(0.019)	(0.010)	(0.016)
$R\times$ NV_{t-1}				−0.094	0.065	−0.159
				(0.122)	(0.054)	(0.119)

Notes: The sample size in each panel is 10,374 observations from 741 U.S. commuting zones over the 2006–2019 period (includes 2005 with lagged value). R is a dummy variable that equals one during 2009–2011 recession, and zero otherwise. All regressions include CZ-fixed and year-fixed effects and observations are weighted by 2005 CZ employment. Standard errors clustered at the CZ-level, and ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

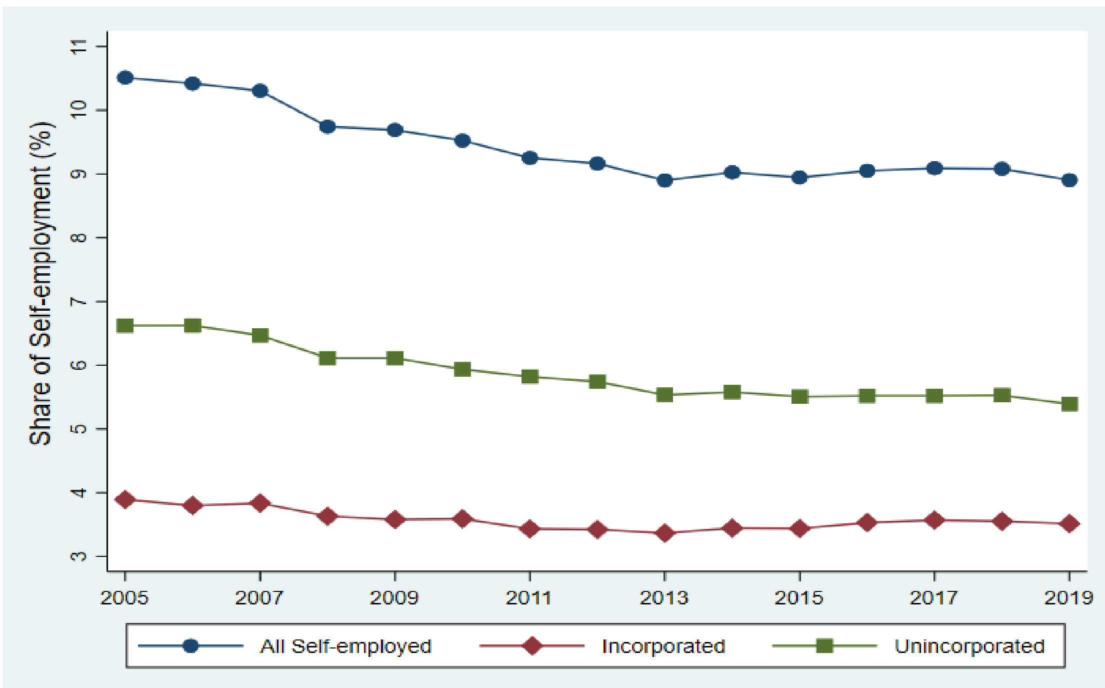
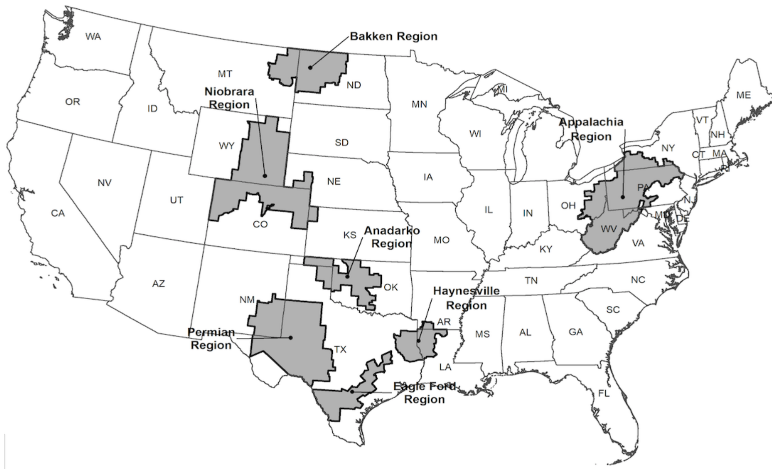
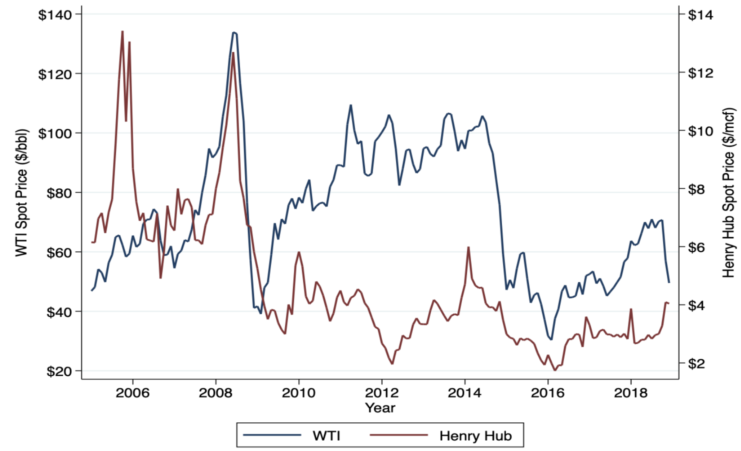


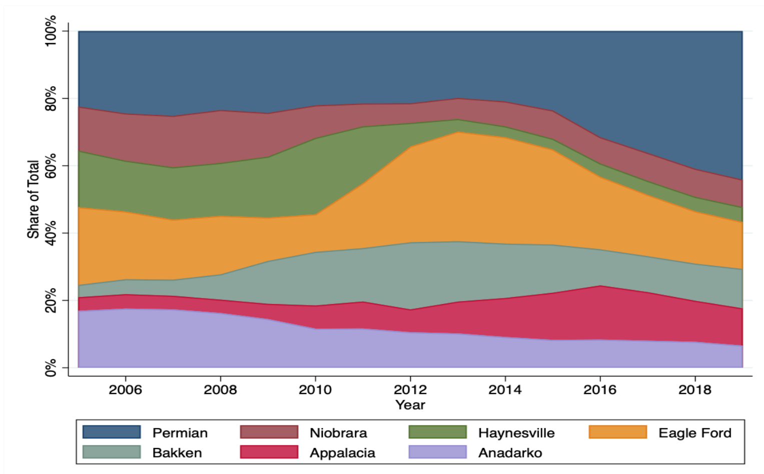
Figure 1: Share of Self-employed Individuals (%)



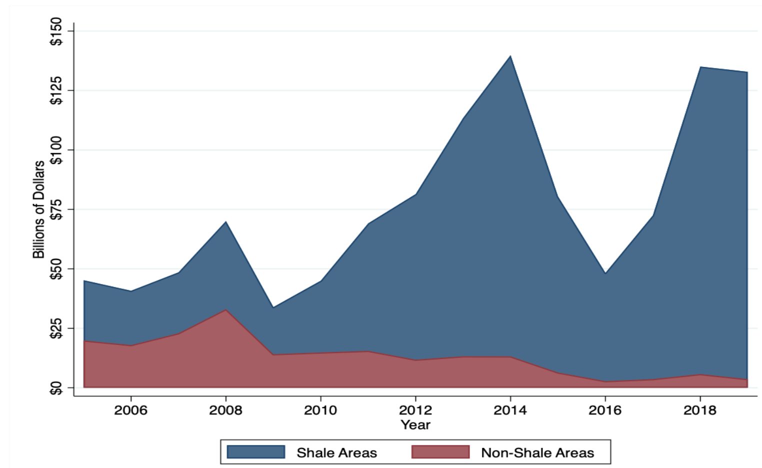
(a) EIA Shale Play Definitions



(b) Oil and Natural Gas Prices



(c) Share of Value by Play



(d) Shale vs. Non-Shale Counties

Figure 2: Oil and Natural Gas Data

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Table A1: Impact of New Oil & Gas Production on Self-employment by Industry

Variable	All 1	Incorp 2	Unincorp 3	All 4	Incorp 5	Unincorp 6
	A. Wholesale & Retail			B. Business & Repair		
NV_t	0.011**	0.001	0.009**	0.006	−0.001	0.007
	(0.004)	(0.003)	(0.004)	(0.006)	(0.003)	(0.005)
NV_{t-1}	−0.006	0.003	−0.009**	−0.004	0.002	−0.006
	0.004)	(0.004)	(0.004)	(0.007)	(0.003)	(0.007)
	C. Personal Services			D. Professional Services		
NV_t	0.016***	0.003	0.013**	0.017**	0.004	0.013*
	(0.006)	(0.003)	(0.006)	(0.008)	(0.004)	(0.007)
NV_{t-1}	−0.011**	−0.003	−0.009	−0.010	−0.000	−0.010
	(0.006)	(0.003)	(0.006)	(0.008)	(0.005)	(0.008)

Notes: The sample size in each panel is 10,374 observations. All regressions include CZ-fixed and year-fixed effects and observations are weighted by 2005 CZ employment. Standard errors clustered at the CZ-level, and ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Table A2: Impact of New Oil & Gas Production on Self-employment: Mining

Variable	All 1	Incorp 2	Unincorp 3	All 4	Incorp 5	Unincorp 6
	A. Log New Values			B. More Controls		
NV_t	0.012**	0.003	0.009*	0.006*	0.002	0.005**
	(0.005)	(0.003)	(0.0093	(0.003)	(0.002)	(0.002)
NV_{t-1}	−0.015**	−0.001	−0.014*	−0.009*	−0.000	−0.009**
	(0.006)	(0.003)	(0.005)	(0.004)	(0.002)	(0.004)
	C. Spatial Spillovers			D. Controlling Migration		
NV_t	0.005*	0.002	0.004*	0.007**	0.003	0.004*
	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)
NV_{t-1}	−0.008*	0.000	−0.008**	−0.011**	−0.002	−0.009**
	(0.004)	(0.002)	(0.004)	(0.005)	(0.002)	(0.004)
	E. Population Trends			F. IV Estimates		
NV_t	0.009***	0.001	0.008***	0.014	0.004	0.010*
	(0.003)	(0.002)	(0.002)	(0.006)	(0.003)	(0.006)
NV_{t-1}	−0.010***	0.000	−0.011***	−0.014	−0.003	−0.011**
	(0.004)	(0.002)	(0.003)	(0.006)	(0.003)	(0.005)
	G. Further Lags			H. Leads		
NV_{t+1}				0.002	0.002	−0.000
				(0.005)	(0.002)	(0.004)
NV_t	0.008*	0.001	0.006**	0.005	−0.000	0.006
	(0.004)	(0.002)	(0.003)	(0.007)	(0.002)	(0.005)
NV_{t-1}	−0.012	0.001	−0.013**	−0.006	−0.000	−0.006*
	(0.008)	(0.003)	(0.007)	(0.004)	(0.001)	(0.003)
NV_{t-2}	0.003	−0.001	0.005			
	(0.004)	(0.002)	(0.003)			

Notes: The sample size is 6,160 observations in Panel C and 10,374 in all other panels. All regressions include CZ-fixed and year-fixed effects and observations are weighted by 2005 CZ employment. Standard errors clustered at the CZ-level, and ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Table A3: Impact of New Oil & Gas Production on Self-employment: Construction

Variable	All 1	Incorp 2	Unincorp 3	All 4	Incorp 5	Unincorp 6
	A. Log New Values			B. More Controls		
NV_t	0.008	−0.003	0.010	0.003	−0.002	0.005
	(0.018)	(0.007)	(0.013)	(0.013)	(0.004)	(0.010)
NV_{t-1}	0.005	0.005	0.002	0.008	0.005	0.003
	(0.017)	(0.008)	(0.012)	(0.014)	(0.005)	(0.010)
	C. Spatial Spillovers			D. Controlling Migration		
NV_t	−0.003	−0.004	0.001	−0.004	−0.005	0.001
	(0.010)	(0.003)	(0.009)	(0.011)	(0.003)	(0.009)
NV_{t-1}	0.009	0.006	0.003	0.014	0.008	0.006
	(0.014)	(0.005)	(0.010)	(0.014)	(0.005)	(0.010)
	E. Population Trends			F. IV Estimates		
NV_t	−0.002	−0.004	0.002	−0.011	−0.012	0.001
	(0.015)	(0.005)	(0.011)	(0.019)	(0.008)	(0.013)
NV_{t-1}	0.016	0.008	0.009	0.019	0.012	0.007
	(0.012)	(0.005)	(0.009)	(0.019)	(0.008)	(0.013)
	G. Further Lags			H. Leads		
NV_{t+1}				0.004	0.006	−0.003
				(0.009)	(0.007)	(0.007)
NV_t	−0.000	−0.004	0.004	−0.006	−0.010	0.004
	(0.016)	(0.005)	(0.012)	(0.017)	(0.009)	(0.015)
NV_{t-1}	0.011	0.010	0.002	−0.000	0.004	−0.005
	(0.024)	(0.010)	(0.018)	(0.009)	(0.004)	(0.008)
NV_{t-2}	−0.004	−0.005	0.001			
	(0.013)	(0.006)	(0.010)			

Notes: The sample size is 6,160 observations in Panel C and 10,374 in all other panels. All regressions include CZ-fixed and year-fixed effects and observations are weighted by 2005 CZ employment. Standard errors clustered at the CZ-level, and ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Table A4: Impact of New Oil & Gas Production on Self-employment: Manufacturing

Variable	All 1	Incorp 2	Unincorp 3	All 4	Incorp 5	Unincorp 6
	A. Log New Values			B. More Controls		
NV_t	0.007	0.003	0.004	0.007	0.003	0.003
	(0.008)	(0.004)	(0.004)	(0.007)	(0.003)	(0.004)
NV_{t-1}	−0.011	−0.005	−0.006	−0.010	−0.005	−0.006
	(0.011)	(0.005)	(0.006)	(0.010)	(0.005)	(0.006)
	C. Spatial Spillovers			D. Controlling Migration		
NV_t	0.008	0.004	0.003	0.008	0.004	0.004
	(0.007)	(0.003)	(0.004)	(0.007)	(0.003)	(0.004)
NV_{t-1}	−0.011	−0.006	−0.005	−0.011	−0.006	−0.005
	(0.011)	(0.005)	(0.006)	(0.010)	(0.004)	(0.006)
	E. Population Trends			F. IV Estimates		
NV_t	0.009	0.004	0.005	0.004	0.005	−0.001
	(0.007)	(0.004)	(0.004)	(0.005)	(0.003)	(0.004)
NV_{t-1}	−0.011	−0.005	−0.007	−0.004	−0.002	−0.002
	(0.008)	(0.004)	(0.004)	(0.005)	(0.003)	(0.004)
	G. Further Lags			H. Leads		
NV_{t+1}				−0.003	−0.002	−0.001
				(0.004)	(0.003)	(0.002)
NV_t	0.009	0.003	0.006	0.013	0.007	0.006
	(0.010)	(0.005)	(0.005)	(0.010)	(0.006)	(0.005)
NV_{t-1}	−0.016	−0.004	−0.012	−0.006	−0.003	−0.003
	(0.018)	(0.009)	(0.009)	(0.005)	(0.003)	(0.003)
NV_{t-2}	0.006	−0.001	0.007			
	(0.008)	(0.004)	(0.005)			

Notes: The sample size is 6,160 observations in Panel C and 10,374 in all other panels. All regressions include CZ-fixed and year-fixed effects and observations are weighted by 2005 CZ employment. Standard errors clustered at the CZ-level, and ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Table A5: Impact of New Oil & Gas Production on Self-employment: Transportation

Variable	All 1	Incorp 2	Unincorp 3	All 4	Incorp 5	Unincorp 6
	A. Log New Values			B. More Controls		
NV_t	0.014*	0.002	0.012**	0.008	0.001	0.007*
	(0.007)	(0.005)	(0.005)	(0.005)	(0.003)	(0.004)
NV_{t-1}	−0.013**	−0.003	−0.010	−0.008*	−0.002	−0.006
	(0.006)	(0.005)	(0.007)	(0.005)	(0.004)	(0.004)
	C. Spatial Spillovers			D. Controlling Migration		
NV_t	0.007	0.001	0.005*	0.007*	0.002	0.006*
	(0.005)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
NV_{t-1}	−0.008*	−0.002	−0.006	−0.008*	−0.002	−0.006
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)
	E. Population Trends			F. IV Estimates		
NV_t	0.009**	0.002	0.007*	0.010**	0.001	0.009**
	(0.004)	(0.003)	(0.004)	(0.005)	(0.003)	(0.005)
NV_{t-1}	−0.005	−0.001	−0.004	−0.009*	−0.000	−0.008*
	(0.003)	(0.003)	(0.004)	(0.005)	(0.002)	(0.005)
	G. Further Lags			H. Leads		
NV_{t+1}				0.004	0.004	−0.000
				(0.006)	(0.003)	(0.004)
NV_t	0.007	0.001	0.006	0.003	−0.003	0.006
	(0.006)	(0.004)	(0.004)	(0.011)	(0.006)	(0.008)
NV_{t-1}	−0.008	−0.002	−0.005	−0.006	0.001	−0.007
	(0.007)	(0.006)	(0.007)	(0.006)	(0.003)	(0.005)
NV_{t-2}	−0.001	0.001	−0.001			
	(0.004)	(0.003)	(0.004)			

Notes: The sample size is 6,160 observations in Panel C and 10,374 in all other panels. All regressions include CZ-fixed and year-fixed effects and observations are weighted by 2005 CZ employment. Standard errors clustered at the CZ-level, and ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.

Table A6: Impact of New Oil & Gas Production on Self-employment: Other Services

Variable	All 1	Incorp 2	Unincorp 3	All 4	Incorp 5	Unincorp 6
	A. Log New Values			B. More Controls		
NV_t	0.076**	0.008	0.068***	0.048***	0.007	0.042***
	(0.030)	(0.013)	(0.024)	(0.017)	(0.007)	(0.014)
NV_{t-1}	−0.052*	0.009	−0.061**	−0.033**	0.003	−0.036**
	(0.027)	(0.013)	(0.024)	(0.016)	(0.008)	(0.015)
	C. Spatial Spillovers			D. Controlling Migration		
NV_t	0.040***	0.004	0.036***	0.045***	0.005	0.040***
	(0.012)	(0.006)	(0.011)	(0.015)	(0.006)	(0.012)
NV_{t-1}	−0.028*	0.005	−0.033**	−0.032**	0.003	−0.035***
	(0.014)	(0.008)	(0.013)	(0.014)	(0.007)	(0.012)
	E. Population Trends			F. IV Estimates		
NV_t	0.039	0.004	0.035**	0.108***	0.021	0.087***
	(0.024)	(0.010)	(0.017)	(0.031)	(0.015)	(0.032)
NV_{t-1}	−0.002	0.016	−0.017	−0.086***	−0.009	−0.077**
	(0.015)	(0.009)	(0.013)	(0.027)	(0.016)	(0.031)
	G. Further Lags			H. Leads		
NV_{t+1}				−0.009	−0.001	−0.008
				(0.015)	(0.007)	(0.012)
NV_t	0.040*	0.003	0.038**	0.058**	0.008	0.050**
	(0.021)	(0.009)	(0.017)	(0.028)	(0.015)	(0.023)
NV_{t-1}	−0.006	0.018	−0.024	−0.046***	−0.002	−0.044***
	(0.027)	(0.013)	(0.023)	(0.017)	(0.010)	(0.016)
NV_{t-2}	−0.026	−0.014	−0.012			
	(0.017)	(0.009)	(0.012)			

Notes: The sample size is 6,160 observations in Panel C and 10,374 in all other panels. All regressions include CZ-fixed and year-fixed effects and observations are weighted by 2005 CZ employment. Standard errors clustered at the CZ-level, and ***, **, and * represent statistical significance at the 1%, 5%, and 10% level, respectively.