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Oil and Gas Boomtowns and Occupations: What Types of Jobs are created?[1]

Isha Rajbhandari[a], Alessandra Faggian[b], and Mark Partridge[c,d,b]

[a] Department of Economics, University of Puget Sound, Tacoma, WA, USA (Corresponding author)

Email: irajbhandari@pugetsound.edu

[b] Gran Sasso Science Institute, L'Aquila, Italy

Email: alessandra.faggian@gssi.it

[c] Agricultural, Environmental, and Development Economics, The Ohio State University, Columbus, OH, USA;

[d] Jinan University, Guangzhou, China;

[b] Gran Sasso Science Institute, L'Aquila, Italy

Email: partridge.27@osu.edu

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1. Introduction

Energy development has been found to impact local economies through a myriad of factors such as jobs, income, education, migration, environment, crime, etc. With innovations in hydraulic fracturing (also known as “fracking”) or micro-seismic technology since the late 1990s, shale oil and gas development has created labor demand shocks spurring growing interest in regional impacts of energy booms on local economic growth. Such interest has been reinforced by the enduring boom-bust energy cycle that in turn transfers its volatility to communities whose labor markets are especially exposed (Weinstein 2014). There are several channels through which shale oil and gas extraction impacts local economies, but most research on the resulting local labor-market outcomes has been at aggregate levels, particularly stressing labor demand and supply responses.

The existing economic literature mostly focuses on estimating the impact on local jobs and earnings growth (Black et al. 2005a; Tsvetkova and Partridge 2016; Weber 2012; Weinstein 2014; Lee 2015; Hoy et al. 2017). Although increasing job opportunities is a favorable regional development, it is useful to assess what ‘types’ of jobs or occupations are being created. Considering that oil and gas booms involve different phases, increasing employment opportunities will likely entail increased demands for workers with varying levels of education and skills. They would work in occupations ranging from relatively low skilled trucking, construction, and drilling occupations to high-skilled engineering positions (Rajbhandari et al. 2020). Therefore, exploring the occupational structure associated with oil and gas booms is important to fully assess the new “human capital” created. Changes in occupational structure could alter the workforce’s human-capital composition in boomtowns, thereby influencing the region’s ability to respond to negative shocks from energy busts and the overall region’s economic resilience (Rajbhandari et al. 2020). However, no study has explicitly examined the relationship between oil and gas developments and occupation-specific job growth. Our study aims to fill this gap.

Our main goal is to highlight the human-capital implications of shale oil and gas development from an occupational structure lens. We examine how labor demand shocks affect occupation-specific job growth by accounting for the 'types' of jobs created in oil and gas booms in the 3,109 counties in the 48 contiguous US states. Using a unique dataset with annual county employment at the 2- and 5-digit 2010 Standard Occupation Classification (SOC) code from the Bureau of Labor Statistics (BLS), this study significantly reduces the within-occupation variation prevalent in previous studies using 1-digit SOC codes. We combine our findings with information on education, experience, and on-the-job training requirements for each occupation from the U.S Department of Labor's Occupational Information Network (O*NET) data to conduct an in-depth analysis of the human capital associated with each occupation. This allows us to better understand the link between oil and gas booms and changes in the human-capital stock in local labor markets.

An augmented first-difference methodology is employed. To further avoid potential endogeneity, we employ an instrumental variable (IV) approach, using two instruments based on geological measures of shale oil and gas resources and past drilling intensity of oil and gas wells. Our study finds that oil and gas development has a significant impact on occupation-specific job growth for 9 out of 19 occupational categories using 2-digit SOC codes. Examples of occupations that experience relatively large job growth include low-skilled derrick, rotary drill, and service-unit operators who have not completed high school with an average of few months to a year of work experience and on-the-job training to human capital-intensive occupations such as engineers and cartographers that require at least a bachelor's degree and an average work experience of up to six years. While there is significant variation in the types of occupations associated with oil and gas extraction, the results suggest that many of these occupations, on average, require workers to have vocational and technical training in addition to a high school diploma, thereby indicating increasing demand for workers with intermediate skills. This is consistent with the disproportionate increase in labor supply of in-migrants with medium-high human capital in areas with oil and gas development (Rajbhandari et al. 2020). Taken together, they illustrate the labor supply and demand effects of oil and gas development and provide useful insights into the impact of oil and gas booms on local labor markets.

The paper is organized as follows. Section 2 briefly summarizes the most relevant contributions in the literature. Section 3 describes the data and the empirical methodology. Section 4 discusses our main results. Finally, Section 5 presents our conclusions.

2. Theoretical background

Studies exploring the effects of unconventional oil and gas extraction on local economies overwhelmingly find significant positive effects (Marchand and Weber 2018). In the United States, these findings are observed specifically in the context of economic variables such as job growth and earnings with some emphasis on median-household income and poverty (Weber 2012; Weinstein 2014; Alcott and Keniston 2015; Lee 2015; Paredes et al. 2015; Tsvetkova and Partridge 2016; Hoy et al. 2017). In their study, Paredes et al. (2015) estimate that each active well in Pennsylvania's Marcellus Shale generates 6 to 16 jobs in the county. Likewise, for the 1970 to 2012 period, Allcott and Keniston (2018) find that a 1% increase in national oil and gas employment increases earnings per worker by 1–3% for each additional standard deviation in oil and gas endowment.

Outside the United States, Fleming and Measham (2014a) find that each new mining job in the Coal Seam Gas (CSG) industry in Australia in the 2000s was associated with 1.8 more non-mining jobs, which primarily reflect jobs created in construction and professional services.

Such widespread positive employment spillovers suggest that offsetting displacement or crowding-out effects are relatively subdued in Australia. Similarly, Marchand (2012) found that 10 new energy extraction jobs created an additional 3 construction jobs, 2 retail trade jobs, and 4.5 services jobs in the four western Canadian provinces during the energy booms of 1970s and 2000s.

Increase in shale oil-and-gas production may result in positive labor demand shocks within the resource-rich geographical areas (Marchand and Weber 2018). Labor demand shocks in energy producing states, on average, account for more than 70% of long-run employment fluctuations.[1] During the 1975-1982 energy boom, energy states experienced the largest labor demand shocks (Partridge and Rickman 2003). Recent economic studies estimating the labor demand impact of shale oil and gas boom focus on overall employment effects (Kinnaman 2011; Weinstein and Partridge 2011; Brown, 2014; Lee 2015; Paredes et al. 2015; Komarek 2016; Hoy et al. 2017).

However, labor demand shocks arising from oil and gas development can result in varied labor-supply responses such as changes in migration flows (Rajbhandari et al. 2020, Vachon 2015; Wilson 2020), educational attainment (Black et al., 2005b; Cascio and Narayan 2020; Morrissette et al., 2015; Rickman et al. 2017; Weinstein 2019), and college major choices (Han and Winters 2020). While there is some regional heterogeneity, migration is the primary supply response in energy producing states (Partridge and Rickman 2006). Increased employment opportunities due to positive energy-related labor demand shocks lead to higher in-migration of workers into the region (Black et al. 2005a; Ruddell et al. 2014; White 2012). Rajbhandari et al. (2020) explicitly analyze this relationship for areas with oil and gas development, accounting for

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[1] Energy states are those that have sufficient energy production. In their study, Partridge and Rickman (2003) specifically focus on Colorado, Louisiana, Montana, Oklahoma, Texas, West Virginia, and Wyoming based on the energy boom of the late 1970s and early 1980s.

the human capital of in-migrants. They find a positive relationship between the oil-and-gas boom and local migration. The impact is disproportionately large for in-migrants with intermediate skills, i.e. workers with some college, 2-years associate degree, or occupational or technical trainings. Thus, it appears that energy regions rely heavily on attracting migrants with skillsets specific to the energy industry.

Although Rajbhandari et al. (2020) may be one of the first to highlight the types of human capital migrating into areas with oil and gas development, others examined the direct human capital implications of energy development. Weber (2014) finds that the workforce in counties with increased shale gas development experience a declining share of high school dropouts and increasing shares in high school graduates, those who attended some college, and college graduates relative to the population. On the contrary, regional energy booms have also been found to reduce average years of schooling for individuals in energy-rich areas (Black et al. 2005; Cascio and Narayan 2020; Kumar 2017; Rickman et al. 2017). In regards to the shale boom, Cascio and Narayan (2020) demonstrate an increase in high school dropouts of male teens and Rickman et al. (2017) find reductions in both high school and college attainment among initial local residents in Montana, North Dakota, and West Virginia. Additionally, energy booms can also influence individual’s college major choices. Han and Winters (2020) find strong evidence of increased prevalence of two energy-related majors i.e. petroleum engineering and geology among young people born in energy states during the 1970s and early 1980s energy boom and a decline during the subsequent energy bust.

Given its long-term implications for growth, it is crucial to investigate the human capital implications of shale oil and gas development (Becker 1962; 1964; Faggian and McCann 2009; Faggian et al. 2017). Likewise, macroeconomic growth models based on endogenous growth theories by Lucas (1988) and Romer (1986; 1990), discuss the central role of human capital in ensuring productivity gains and sustained long-run growth (Feser 2003; Gabe 2009). A substantial body of literature has documented the positive externalities of human capital on local labor markets (Moretti 2004a; 2004b; 2004c; Rauch 1993; Shapiro 2006; Winters 2011a; 2013). Occupation-based human-capital measures are increasingly used as a proxy for the role of occupation-based strategies in fostering regional growth (McKeen and Froeschle 1985; Markusen 2004; Thompson and Thompson 1985; 1987; Ranney and Betancur 1992). The returns to human capital vary widely across occupations, making it important to account for differences in how occupation-specific skills are valued in the labor market (Sullivan 2010). Winters (2014) finds significant positive wage externalities in metropolitan areas associated with both STEM and non-STEM college graduates, with the magnitude being larger for STEM graduates.

This study, specifically building on the work of Rajbhandari et al. (2020), highlights the human capital implications of shale oil and gas development from a labor demand lens. Considering that the oil and gas boom entails multiple phases from the initial gathering of local mineral rights, to the active drilling, to being a mature oilfield, these booms will likely increase the employment opportunities for individuals with varying levels of education and skills. Therefore, we explore occupation-specific job growth in oil-and-gas boom counties across the 3,109 counties in the 48 contiguous U.S. states using unique occupation-specific employment data. We aim to bridge the gap in the literature by explicitly examining-the kinds of occupations that are in demand for regions with oil and gas booms and their human capital requirements. Moreover, given the likelihood that these new jobs are being filled by migrants who already have the relevant skills, the findings of this study can help influence workforce-training policies to train the workforce in boom areas that focus on technical training of local workers, ultimately impacting the local economy’s ability to respond to the energy shocks (Diodato and Weterings 2015).

3. Data and Empirical Modelling

Data sources. The occupation data includes the number of jobs in each occupational category at the 2- (major) and 5-digit (broad) 2010 SOC System. Likewise, to derive oil and gas employment, 4-digit North American Industry Classification System (NAICS) level data is required. Such data is unavailable from public sources. Thus, we acquired this data from Economic Modeling Specialists, Inc. (EMSI), a widely used data source in research and by organizations such as the Brookings Institute. EMSI uses a proprietary process in data construction.[2] The resulting sample is at the county level for the 48 contiguous US states, producing a sample of 3,109 counties for each year over the 2005 to 2014 study period.[3] A description of the main variables and their sources is in *Table 1.*

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[2] Vendors producing employment estimates at a fine industry level begin with public government data, which is suppressed in cases when the government fears that a given firm's identity may be revealed. Private vendors like EMSI need to estimate those values. EMSI's process for filling suppressed values is proprietary but it appears accurate and is unlikely to meaningfully affect our results (see Weinstein et al., 2018's similar discussion). For example, oil and gas county-level employment in the Bureau of Labor Statistics *Quarterly Census of Employment and Wages* (QCEW) is reported for about 20% of all counties that account for over 80% of national employment. For the remaining counties with suppressed oil-and-gas employment values (which EMSI creates estimates), the leverage of those observations is quite small in our regressions for two reasons. First, given that less than 20% of total national oil and gas employment needs to be "distributed" by the EMSI data imputation algorithm among about 80% of the remaining counties, the values of oil and gas employment in such cases should be close to zero. Second, our main energy explanatory variable (differenced growth in oil and gas employment) is calculated relative to *total* county employment. This further reduces the possibility of an observation with a small energy industry to influence the estimation results because, by construction, growth in a small sector relative to the total county economy (as opposed to its growth relative to own values in the past) is a very small number. Moreover, the correlation between QCEW and EMSI oil and gas employment using unsuppressed QCEW values is 0.995 (Weinstein et al., 2018). Weinstein et al. (2018) acquired unsuppressed U.S. Census Bureau *County Business Patterns* (CBP) data from the Upjohn Institute for Employment Research that uses linear programming for estimating CBP's suppressed values (Isserman & Westervelt, 2006). The correlation between Upjohn's CBP oil-and-gas employment with EMSI's oil-and-gas employment is 0.960. Note that this correlation is slightly higher than the correlation of Upjohn's CBP data with unsuppressed QCEW data, further supporting the accuracy of EMSI's oil and gas data.

[3] Appendix Figure A.1 presents a map depicting the counties in the 48 contiguous US states, which represents our sample for this study. Hawaii and Alaska are not included in the analysis. Appendix Table A.2 presents the descriptive statistics of the top-10 counties based on how much oil and gas employment *directly* affected total employment growth in the 2010-2014 boom period. Appendix Figure A.3 has two maps that show the 10 counties.

Table 1: Variable Descriptions

Variable name	Description	Source
Dependent variables Δoccupation$_{io}$	The percentage change in total employment due to the change in occupation *o's* employment in year *t* minus the percentage change in total employment due to the change in *o's* employment in year *t-1*. [4]	EMSI; 2005-2014
Independent variables		
ΔOil-and-gas employment or $\Delta oilandgasemp_{it}$	The change in county *i*'s oil-and-gas *employment-level* between periods *t* and *t-1* divided by *total* county employment in *t-1* ***minus*** the analogous oil-and-gas variable measured in periods *t-1* and *t-2*.[5]	EMSI; 2005-2014
Oil and gas employment share or $oilandgasshare_{it}$	The oil-and-gas total employment share in period *t*, or oil-and-gas employment in *t* divided by total county employment in *t*.[6]	EMSI; 2005-2014
Industry Mix Growth Rate	Predicted growth rate if all industries excluding the oil and gas sector grow at the national growth rate[7]	EMSI; 2005-2014
% Bachelor's degree	Percent of individuals over the age of 25 with a college degree in 2000	Economic Research Service (ERS); 2000
Population density	Population density in 2000	U.S. Census Bureau; 2000
Log wage and salary income	Log of wage and salary income in 2000	Regional Economic Information System (REIS) ; 2000
Nonmetro counties	Indicator for nonmetropolitan county	U.S. Census Bureau, 2003 definition
Natural Amenities Index	The county's natural amenity ranking on a 1 to 7 scale	USDA; 2000

At the major level, we only study the 19 major occupational categories that are related to

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[4] Calculated as: $\Delta occupation_{iot}(\Delta y_{iot}) = 100 \times \{\left(\frac{countyjobs_{iot} - countyjobs_{io(t-1)}}{totalcountyjobs_{i(t-1)}}\right) - \left(\frac{countyjobs_{io(t-1)} - countyjobs_{io(t-2)}}{totalcountyjobs_{i(t-2)}}\right)\}$

[5] Calculated as: $\Delta oilandgasemp_{it} = 100\ \times \{\left(\frac{oilandgasemp_{it} - oilandgasemp_{it-1}}{totalcountyemp_{it-1}}\right) - \left(\frac{oilandgasemp_{it-1} - oilandgasemp_{it-2)}}{totalcountyemp_{it-2}}\right)\}$

[6] Calculated as: $oilandgasshare_{it} = \frac{oilandgasemp_{it}}{totalcountyemp_{it}}$

[7] Calculated as: $Industrymix_{it} = \sum_s S_{ist-1} NG_{st,t}$, where S_{ist-1} refers to the employment share of industry s (where *s* does not include NAICS 2111 or NAICS 2131) in county i in the beginning of the period and $NG_{st,t}$ refers to the national employment growth rate in industry *s* during the period *t*.

the Oil and Gas Extraction (NAICS 2111) and Support activities for Mining (NAICS 2131).[8] We use the broad occupational groups for in-depth analyses of the types of jobs associated with oil and gas development, as well as their education and training requirements at a finer scale. Using the information, we can explore how changes in occupational job growth influence the types of human capital demanded by areas with oil and gas development, and infer its impact on regional growth and local labor market composition.

The oil-and-gas employment variables proxy for both *growth* and *level* effects of shale development. They are specifically defined in Table 1 and are described more below. They include employment in oil and gas extraction (NAICS code: 2111) and support activities for mining (NAICS code: 2131). Directly using oil-and-gas employment (versus other measures like number of oil wells drilled) allows us to accurately account for the size of the energy-sector's impact on the local labor market—e.g., number of drilling rigs would only indirectly affect the local labor market through its employment impacts on the oil and gas sector. The initial *pre-drilling stage*, which involves acquisition of drilling rights and construction of some infrastructure, and the *final stage*, which involves operating the oil and gas fields, have considerably fewer employees (Kelsey et al, 2016; White, 2012). About 80% of boom employment occurs during the middle drilling and construction phase. Thus, studies using data on oil and gas production (Weber 2012; Peach and Starbuck 2011) or earnings (Haggerty et al. 2014) to proxy for the scale of the sector's impact on the local labor market are using weaker proxies of the intensity of oil-and-gas impacts.

The industry-mix growth rate variable, also referred to as a demand shock, is obtained

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[8] The occupational categories included in the study are not exhaustive. There are overall 23 major occupational profiles defined by the Occupational Employment and Wage Statistics (https://www.bls.gov/oes/current/oes_stru.htm). Of these 23, we focus on the 19 occupation categories related to the Oil and Gas sector as shown by the Occupational Employment and Wage Statistics. The descriptive statistics for the 19 relevant occupational categories are presented in Appendix Table A.1. Additional information is at: https://www.bls.gov/oes/current/naics4_211100.htm and https://www.bls.gov/oes/current/naics4_213100.htm.

from shift-share analysis (Bartik 1991; Partridge and Rickman 1999; Tsvetkova and Partridge 2016). The formula for calculating the industry-mix employment growth rate is in footnote 7. It measures the percentage change in total county employment if all of its industries grew at the national growth rate—i.e., it reflects whether the county has a composition of relatively fast or slow-growing industries (Betz et al. 2015). It is typically assumed to be exogenous to the modelled relationships as it utilizes the county's initial industry composition and projects industry growth based on their national employment growth rates, which are not influenced by growth dynamics of a single county (in other settings, it is called the "Bartik" instrument because it is assumed to be exogenous). In this calculation, we omit the oil and gas sector to allow us to compare the *oil and gas* and the *overall* industry-mix regression coefficients to ascertain whether the effect of an oil and gas shock on occupation-specific job growth differs from an equal-sized average shock from industries outside of the oil and gas sector (Tsvetkova and Partridge 2016).

In order to analyze the human capital impacts of oil and gas development, we use the information on education, experience, and training requirements for each occupation from the O*NET database (version 21.2) for the broad occupational categories.[9] O*NET provides comprehensive descriptions of each occupation including information about the work and worker characteristics, along with their skill requirements. The education, experience, and training variables measure the amount of education, work experience, and on-the-job training required in a specific occupation. The attributes for each job are obtained from the O*NET survey, which include questions on educational categories ranging from less than high school diploma to post-doctoral training, and work experience and training durations ranging from less than 1 month to

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[9] O*NET is conceptually organized in six dimensions, each characterizing one aspect of a detailed set of occupations: *worker characteristics* (abilities, interests, & work styles); *worker requirements* (basic and cross-functional skills, general knowledge, & education); *experience requirements* (training, experience, licensing); *occupation requirements* (work activities and context, organizational context*); occupation-specific information* (knowledge, skills, tasks, & machinery/equipment); and *occupational characteristics* (e.g., wages and labor-market outlook) (Feser, 2003).

8-10 years. Following Gabe and Abel (2012) and Feser (2003), we use the percent of O*NET survey respondents in each broad category to calculate the average levels of education, experience, and training required by workers.

Empirical Model. We use 2005 to 2014 annual data in adopting an augmented first-difference empirical model following Duranton and Turner (2011), Duranton (2016), and Tsvetkova and Partridge (2016). Differencing over one-year time periods removes the unobservable county fixed effects that could bias the results. Moreover, differencing is advantageous over panel models that use fixed effects because it allows us to control for persistent disequilibrium-*level* variables that may have intervening effects in how oil booms evolve over the period under consideration. Aside from county fixed effects, there could be historical factors that persistently affect contemporaneous job growth during energy booms.[10] For example, counties with greater pre-boom educational attainment or counties that were very sparsely populated may have differing responses to oil booms. Equation (1) shows the empirical model:

$$(1)\ \Delta y_{iot} = \alpha + \beta \Delta oilandgasemp_{it} + \gamma oilandgasshare_{it} + \pi \Delta industrymix_i + \varphi education_{i2000} + \delta popdensity_{i2000} + \mu naturalamenities_{i2000} + \rho logwageandsalary_{i2000} + \lambda nonmetro_{i2003} + \boldsymbol{\theta}_s + \boldsymbol{\tau}_t + \varepsilon_i$$

where o is the occupation, i is county, t is year which falls between 2005 to 2014. Refer to footnote 5 for the formula defining Δy_{iot}. In words, Δy_{iot} is the percentage change in *total* employment due to the change in occupation *o's* employment in *year t minus* the percentage change in total employment due to the change in *o's* employment in *year t-1.*[11] Thus, the dependent variable

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[10] Our empirical method also provides flexibility to use a continuous treatment variable instead of setting a threshold that defines whether the county is a "treated" boom county. Thus, we retain all pertinent oil-and-gas-employment information. Using annual data allows us to not confound boom and bust effects which can be comingled when examining changes over multiple years—e.g., late 2008 to late 2009 was the Great Recession bust in oil drilling.

[11] For example, assume that in year *t*, occupation *o's* direct contribution to total employment growth equaled 0.7% and in year *t-1*, *o's* corresponding contribution to total county employment growth was 0.4%. Thus, for period *t,* the dependent variable for *o* would be the difference in the two growth rates, or **0.3 (i.e., 0.7% – 0.4%)**. In words, the

measures the contribution of changes in *o's* employment to how much county *i's* total-employment growth rate changed between years *t* and *t-1* (in percentage terms). Note that for year *t,* if we sum the percentage-change in total employment due to the employment changes in occupation *o* across all *n* occupations (*o*=1, 2,….*n*), , the total would equal *percent change in county i's* ***total*** *employment in year t.* We conduct separate estimations for the 19 major occupational categories that are statistically influenced by the oil and gas sector.

The $\Delta oilandgasemp_{it}$ variable represents the main explanatory variable and is calculated in an analogous fashion as the dependent variable (see footnotes 5 and 6). It measures the direct contribution of changes in oil-and-gas sector jobs to the percentage change in the *total county employment growth rate* between periods *t* and *t-1*. Dividing by total-county employment allows us to scale employment growth in the oil and gas sector relative to overall total county employment. Given that the dependent variable and the oil-and-gas percentage change variable are both measured as their relative to contribution to the percentage change in county i's *total* employment, the oil-and-gas regression coefficient can be interpreted as a multiplier (Tsvetkova and Partridge 2016). That is, this oil and gas regression coefficient is defined as the *percentage change* in occupation *o*'s employment-growth rate between periods *t* and *t-1* after a one-percentage-point increase in the contribution of the oil-and-gas sector's employment growth to total employment (i.e., the definition of a local employment multiplier).[12] Below, this variable

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value of the dependent variable means that the percentage change in *total* employment growth rates between years *t* and *t-1* that is directly due to changes in occupation *o* is 0.3 percentage points.

[12] For example, take the straightforward case of the total-employment multiplier. If between years 1 and 2, the oil and gas sector's direct contribution to the percentage change in total job growth equaled one percentage point, then the multiplier would equal the expected percentage-point change in total employment growth after all spillover effects, *which is equivalent to what the oil-and-gas regression coefficient represents*. If the coefficient equals 1.5, then total employment is expected to rise 1.5 percentage points for every one percentage-point contribution to total employment growth from the oil and gas sector. Of course, this is the same as stating that for every one job created in the oil and gas sector, total employment is expected to increase by 1.5 workers. Alternatively, assume the county had a total employment of 100,000 in year 1. If the oil and gas sector contributed a 1 percentage point increase in total employment between years 1 and 2, that would be the equivalent of the oil and gas sector's employment rising

will generally be referred to as the "percentage change in total employment growth between years t and $t\text{-}1$ that is directly due to oil-and-gas employment growth during the same period."

The oil-and-gas industry total employment share ($oilandgasshare_{it}$) is added to the model to capture whether the evolution of the local economy is affected by the size of the oil and sector in year *t.* For example, if the oil and gas sector is a large share of the local economy, it may be that continued oil-and-gas sector employment growth increasingly displaces or crowds-out a relatively larger share of employment in other sectors. Conversely, if the sector is relatively small, growth in the oil-and-gas sector may be more easily accommodated, meaning other sectors are not facing large displacement effects. The formula for the oil-and-gas industry employment share variable is in footnote 7, though the variable is simply the sector's share of total county employment.

The $\Delta industrymix_{it}$ variable also takes the difference of the industry-mix employment growth rates between years *t* and $t\text{-}1$. Given the definition of the industry-mix variable, it also measures the percentage-change contribution to total employment growth between years *t* and $t\text{-}1$ that originate from other sectors besides oil and gas. Controlling for industry-mix accounts for other industry-based demand shocks (besides oil and gas shocks) that could cause omitted-variable bias if it was not in the model.

After including year fixed effects (with county fixed effects differenced out), the model would be the standard first-difference approach (assuming the oil-and-gas employment share was not included). However, if the local economy is in disequilibrium, which is likely the case if it is undergoing a boom, then adding key historic control variables would account for how these key level variables affect the evolution of local boom economies. In other words, these *level*

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by 1,000. If its regression coefficient equaled 1.5, then total employment growth would be expected to rise by 1.5 percentage points, or by 1,500 jobs—i.e., a shock of 1,000 new oil and gas sector jobs creates 1,500 jobs overall.

variables have *persistent effects* that eventually recede when the economy returns to equilibrium (which is why they are not be part of the *county fixed effects*). On the other hand, if there are **no** persistent disequilibrium factors associated with the level variables, they will be statistically insignificant (which they are not). If that was the case, the level variables should be omitted and the model reverts to a standard first-difference model.

The first set of lagged-level variables in the model are the year 2000 values of the percent of individuals over the age of 25 with a college degree ($education_{i2000}$), population density ($popdensity_{i2000}$) and log of wage and salary income ($logwageandsalary_{i2000}$). These variables control for historic human capital, agglomeration economies, and wage conditions in the county (Tsvetkova and Partridge 2016; Weinstein and Partridge 2011; Weber 2012). For example, population density may have persistent effects on how the local economy responds to oil and gas sector shocks due to agglomeration economies. Most boom counties are rural in nature and lack agglomeration economies. For especially the most sparsely-populated boom counties such as in northwest North Dakota, their small scale means they lack firms that could tap into the energy-sector supply chain. The lack of supply-chain industry growth means that as the boom matures, the county will have less supply-chain related employment growth than more populated areas.

The model also includes a natural-amenity measure ($naturalamenities_{i2000}$) because amenities have a large influence on US migration patterns. To control for proximity to metropolitan areas that may affect spatial spillovers during energy booms, a nonmetropolitan (rural) county dummy variable ($nonmetro_{i2003}$) is included. Moreover, we add state fixed effects (θ_s) to account for any state-level time-invariant spatial characteristics including regulatory differences that alter local booms—e.g., New York state banned fracking. Year fixed effects (τ_t) are added to control for national trends including cyclical effects from the Great

Recession or annual shifts in world oil prices. Standard errors are clustered within US Bureau of Economic Analysis (BEA) economic areas.

The first-difference methodology removes the county fixed effects, meaning we account for unobserved time-invariant attributes specific to counties. For example, "pro-business" locales and/or areas desperate for growth are more likely to facilitate energy extraction compared to places that are economically vibrant and/or fear environmental and health impacts. Yet, counties may have other unobservable factors that change over time. Changes in these unobservable factors could alter whether the industry develops an area, creating *temporal* endogeneity, e.g., anti-fracking politicians gain power sometime during the sample period.

We, therefore, use instrumental-variable (IV) estimation with two instruments: (1) a geological measure of whether the county possesses shale with sufficient oil and gas drilling potential and (2) a measure of the area's historical drilling legacy that affects available infrastructure such as pipelines (Tsvetkova and Partridge 2016; Weber 2012; 2014; Weinstein 2014). The specific instruments are (1) each shale-play's average thickness of the shale containing oil and gas deposits; and (2) the number of square miles with oil-and-gas wells in the 1980s. The geological instrument reflects the predetermined availability of oil and gas reserves whereas the drilling intensity in the 1980s accounts for the history of oil and gas production. Both instruments are assumed to be conditionally exogenous (which we check) because the key factors accounted for by the model should remove from the residual any effects correlated with the instruments.

The decision to drill in a county depends on potential profitability. Considering that shale energy technology evolves over time and year-to-year variation in world oil and gas prices influence profitability, it is important the instruments account for potential time-varying endogeneity, which may not be the case using *static* geological and historic instruments. Thus, we follow Tsvetkova and Partridge (2016) and interact the instruments with time dummies to allow them to have time-varying explanatory power. Below, we test whether the instruments are weak.

4. Results and discussion

Appendix Table A.la reports the annual employment-growth descriptive statistics for the for the 19 major occupations. There are 31,090 sample observations (10 years × 3,109 counties) in the sample. The definition of these occupation variables is the annual percentage-change in total-employment growth that is directly due to the change in the occupation's employment. See the notes to Table A.1a for a formula showing how the variables is derived. For example, Business & Financial Operations directly contributed an average of 0.007 percentage points to the county's total annual employment growth over the 2005-2014 period. The occupation's contribution to annual total employment growth ranged from -0.09 percentage points for Production occupations to 0.059 percentage points for Food Preparation and Serving occupations.

Appendix Table A.2 provides descriptive statistics for the top-10 oil-and-gas boom counties over the 2010-2014 oil-boom period (also see footnote 17 for more details). For number one ranked Dunn County, North Dakota, the oil and gas sector directly contributed 77 percent of its *total* job growth, indicating that job growth did not spread widely beyond the oil and gas sector. On the low end, the corresponding direct employment contribution of the oil and gas sector was 29 percent in Dimmit County, TX. A remarkable feature of the top-boom counties is their very small 2010 population that ranged from 417 in Kenedy, County, Texas to 22,589 in Williams County, North Dakota. It is unsurprising that 9 of these counties are nonmetropolitan, while the only metropolitan county—Irion County, Texas—only had 1,607 residents in 2010. These boom counties are definitely quite rural and are generally quite remote from urban centers.

We now estimate *Equation (1)* to measure the impact of oil and gas development on job growth for 19 major occupational categories. Overall, the results reported in *Table 2* (base model) show a significant positive impact on total job creation.[13] With the overall county employment growth as the dependent variable, the resulting job multiplier estimate of 1.05 suggests that for every one additional job in the oil and gas sector is associated with 1.05 more total jobs in the economy, which falls within the range of overall rural and urban multipliers (Tsvetkova and Partridge, 2016; Partridge et al. 2017). [14]

Table 2: Total job growth OLS estimation results

Variable name	Change in total job growth
Change in oil and gas growth	1.05***
Energy share	-0.27
Change in industry mix growth rate	0.07**

Significance: ***p<0.01, **p<0.05, and *p<0.1.
Note: (i) Standard errors are clustered at BEA area level.
(ii) Change in oil and gas employment is measured as base-period *t's* percentage change in total employment directly due to oil and gas employment growth minus its value for the preceding year *t-1*.
(iii) The dependent variable and independent variables are calculated for the period 2005-2014.

4.1. Results for OLS estimation for major occupational groups (2-digit SOC)

The OLS results for 19 major occupational categories are reported in *Table 3, Panels A, B* and *C*.[15,16] Considering our main explanatory variable—percentage change in annual *total*

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[13] Appendix: Table A.3: The full set of OLS results for the total job growth.

[14] We do not follow Moretti (2010) and Fleming and Measham's (2014b) approach to calculate the job multiplier. This is due to many issues, but the nonlinearity of Moretti approach appears most problematic. In our case, that approach produced multiplier estimates that are heavily influenced by the relative employment shares in the sectors being considered (also see Van Dijk 2018). The problem is magnified in cases like ours in which the oil the gas sector represents an infinitesimal share of total county employment for the vast majority of the sample. However, we assessed how the multipliers would be influenced if we instead had used Moretti's (2010) approach. The overall OLS job multiplier derived using Moretti's (2010) approach is 1.77. This suggests that every 10 additional jobs created in the oil and gas sector is associated with another 7.7 jobs being created in elsewhere in the local economy. As expected, the Moretti OLS multiplier is greater in magnitude than when using our approach with the base-OLS model (Table 2). Van Dijk (2018) shows that this is typical when comparing Moretti's approach to multipliers derived from linear approaches. In fact, when more closely following Moretti's (2010) approach by using IV to estimate the model, using Moretti's derivation yielded an oil-and-gas sector multiplier of 11.8, which is far outside the realm of plausibility and inconsistent with every other study we are aware of. Here, the nonlinearity appears to blow-up the Moretti-multiplier estimates. In contrast, our linear approach does not produce such anomalous results. Rather our results are consistent with the existing literature. One potential reason is the current method scales energy-sector employment to be on the same metric as total employment by scaling the energy-sector's employment effects to total employment.

[15] Appendix Tables A.4 and A.5 contain the full set of first-difference results for the 2-digit SOC-code occupations.

employment growth directly due to oil and gas employment growth—the results show a significant positive impact of oil and gas development on job growth in 12 of 19 major occupation groups. Construction and extraction occupations receive the largest spillover in job growth. Their multiplier estimate of 0.504 suggests that for every 10 jobs created in the oil and gas sector, an additional 5 construction occupation jobs are created. There is no statistically-significant influence for these occupations: art and design; healthcare; protective services; food preparation; building and grounds cleaning and maintenance; personal care; and farming, fishing, and forestry. Unfortunately, it is not possible to distinguish whether these responses are due to job shifts between occupations or actual occupation growth as a result of oil and gas development. Thus, these multiplier estimates should be interpreted as the net effect of both.

The results show heterogeneous impacts of oil and gas share across the major categories. Architecture and engineering, and social-science occupations experience significantly positive job growth in counties with higher initial shares of the oil and gas sector. Interestingly, occupations directly related to the oil and gas sector such as construction and extraction, and transportation and material moving experience significant negative growth. A large existing energy sector might imply that the associated infrastructure is at least partially in place, resulting in a lower demand for additional construction and support workers.

The industry-mix employment-growth rate variable has a significant positive impact on occupation-specific job growth for engineering; food preparation; building and grounds cleaning and maintenance; and production occupations. Compared to the industry-mix coefficients, the oil

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[16] In order to test whether the local oil-and-gas multiplier estimates are equal across all 19 2-digit SOC occupation categories, we use the *suest* command in Stata. While the *suest* command is for Seemingly Unrelated Regressions (SUR), we can jointly estimate all 19 occupation equations simultaneously using SUR and test whether the multiplier regression coefficients are equal across all the equations (note that because the explanatory variables are the same in all 19 models, the SUR results equal the OLS results). *suest* is a post-estimation command that conducts a Wald test that is more efficient for cross-model hypotheses. As expected, the Wald statistic equaled 3,153.7, which leads us to strongly reject the null hypothesis that the oil and gas multiplier is equal across all occupation categories.

and gas shock coefficients are smaller in magnitude for food preparation, and grounds cleaning and maintenance occupations, which suggests that they are more responsive to equal-sized employment shocks outside the oil and gas sector. Yet, the oil and gas coefficient for the engineering and production occupation are larger, which implies that occupations directly related to drilling experience larger growth from oil and gas development relative to an equal-sized shock outside the sector.

Table 3: Major group estimation results (2-digit SOC codes)

Panel A

Dependent variable: Change in occupation-specific job growth

Variable name	Management	Business	Computer	Engineering	Social sciences
Change in oil and gas growth	0.048***	0.027***	0.005***	0.038***	0.018***
Energy share	-0.017	0.008	0.005	0.035***	0.021***
Change in industry mix growth rate	-0.0001	0.002	0.001	0.004**	0.001

Panel B

Dependent variable: Change in occupation-specific job growth

Variable name	Legal	Arts & Design	Healthcare	Protective Service	Food Preparation
Change in oil and gas growth	0.007***	-0.003	0.003	0.001	-0.002
Energy share	-0.001	-0.008	0.011	0.026	-0.006
Change in industry mix growth rate	-0.00004	0.0005	0.001	0	0.009***

Panel C

Dependent variable: Change in occupation-specific job growth

Variable name	Cleaning & Maintenance	Personal care	Sales	Office Admin	Agriculture
Change in oil and gas growth	0.001	0.004	0.037***	0.071***	0.0072
Energy share	-0.012	-0.005	-0.041	-0.035	-0.005
Change in industry mix growth rate	0.005*	0.005	0.003	0.007	-0.0004

Panel D

Dependent variable: Change in occupation-specific job growth

Variable name	Construction	Installation	Production	Transportation
Change in oil and gas growth	0.504***	0.067***	0.051***	0.176***
Energy share	-0.239***	0.010	-0.013	-0.128*
Change in industry mix growth rate	0.001	0.003	0.031***	0.005

Significance: ***p<0.01, **p<0.05, and *p<0.1.

Note: (i) Standard errors are clustered at BEA area level.

(ii) Occupations are defined at the 2-digit 2010 Standard Occupation Classification Codes (i.e. major group).

(iii) Change in oil and gas employment is measured as base-period *t's* percentage change in total employment directly due to oil and gas employment growth minus its value for the preceding year *t-1*.

(iii) The dependent variable and independent variables are calculated for the period 2005-2014.

Given that shale energy development is mostly concentrated in rural areas, we analyze whether some occupations in rural counties experience relatively larger growth. Contrary to our expectations, nonmetropolitan areas overall experience less job growth suggesting a larger impact of agglomeration economies. The employment data is by *place-of-work* and considers all (paid) jobs at establishments in the county (including nonprofits and government). Thus, employment includes both residents and nonresidents, *regardless of place-of-residence.* The importance is that the oil-and-gas industry's workforce is composed of local residents, in-commuters, and workers who "in-migrated" to the drilling site from elsewhere (Hoy et al. 2017; Wrenn et al. 2015).[17] Thus, some of the new oil and gas earnings for these non-local workers leak out of the county. For example, Weinstein et al. (2018) found that just over 15% of new earnings generated from an energy shock leaks out of the county, which reduce *local* multiplier effects.[18,19]

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[17] To give a feel for the origins of the in-migrants to oil-and-gas boom-counties, we examined the top-10 counties in terms of having the largest percentage increase in energy employment as a share of total-county employment in the 2010-2014 boom. Appendix Table A.2 lists these 10 counties along with each county's corresponding origin county of their largest number of in-migrants (using 5-year 2014 *American Community Survey* migration data). Dunn County, ND had the greatest percent increase in total employment *directly* from energy employment. It received the most in-migrants from neighboring Stark County, ND. Nearby Williams County, ND received the most in-migrants from Barry County, MO.

[18] Shale-boom counties are almost exclusively rural. Rural counties lack the scale to have a local supply chain for inputs, meaning business-service expenditures leak out [they also have very few (usually small) firms]. Similarly, they lack retail/hospitality establishments for residents to spend locally, causing more leakage. Together, this means rural counties will general have small *local* employment multipliers. Another feature affecting our multiplier is that U.S. private *mineral-right* owners receive royalties and lease payments for their property's oil and gas production, which can be quite substantial. Yet, the surface-land owner may not be the same as the owner of the mineral rights. Indeed, the share of *absentee mineral-rights owners* can be rather large, creating further leakages (Hoy et al. 2017). Reinforcing this effect is such royalties and lease payments—even if they are made to local residents—are often saved/invested and are not spent locally (Hoy et al. 2017).

[19] Not everyone desires living in the midst of a resource boom, facing an influx of temporary residents (mostly young men). Boom towns often face many social and environmental ills including increased drug and alcohol use, higher crime, reduced public health, lower-quality-of-life, more air and water pollution, greater dust, increases in sexually transmitted diseases, and crowded roads from heavy truck traffic (e.g., see Shakla and Sohag 2021). These adverse effects are reinforced by higher housing costs from increased housing demand of the relatively well-paid transitory workforce—which pushes some existing residents to leave. On average, despite the positive short-term employment effects, Tsvetkova and Partridge (2016) find that energy booms are associated with short-term population loss, which then recovers in about three years. The resulting loss of household income reduces local sales, further dampening economic multipliers. For an extreme case, using U.S. Energy Information Agency data, Ohio, Pennsylvania, and West Virginia produced a combined total of 3% of U.S. natural gas in 2009. By 2020, their share reached 35.1%. U.S. Census Bureau data indicates that this "natural-gas boom" did not produce population gains. In the top-22 natural-gas producing counties in Ohio, Pennsylvania, and West Virginia (O'Leary (2021) lists the 22 counties), 21 lost population between 2010 and 2020 versus only 11 the prior decade. Similarly, 21 of 22 grew less during 2010-2020 than during 2000 to 2010. Moreover, the 22 boom counties grew 3.4% less than the rest of Ohio, Pennsylvania, and West Virginia combined during the "pre-boom" 2000-2010 period, but the gap *widened* to 5.1% in the 2010-2020 "boom" decade.

4.2. Results for instrumental variable estimation for major occupation groups

As noted earlier, we employ an IV approach to avoid potential endogeneity. The overall results are presented in *Table 4* and the occupation-specific results are presented in *Table 5, Panels A, B, C*, and *D*.[20, 21] The IV results reported in Table 4 show a statistically significant positive impact of oil and gas development on overall county employment growth, consistent with the OLS results. The job-multiplier estimate of 1.02 suggests that every added job in the oil and gas sector is associated with 1.02 total new jobs, which is consistent with the range found in some other studies find (e.g., Tsvetkova and Partridge, 2016; Partridge et al. 2017). The modestly smaller multiplier using IV is consistent with the expectation that OLS results are positively biased.

Table 4: Overall total job growth: Instrumental Variable results

Variable name	Change in total job growth
Change in oil and gas growth	1.019***
Energy share	-0.26
Change in industry mix growth rate	0.074**
First-Stage Weak Instrument F-stat.	53.05
Over-identification test p-value	0.048

Significance: ***p<0.01, **p<0.05, and *p<0.1.
Note: (i) Standard errors are clustered at BEA area level.
(ii) Change in oil and gas employment is measured as base-period *t's* percentage change in total employment directly due to oil and gas employment growth minus its value for the preceding year *t-1*.
(iii) The dependent variable and independent variables are calculated for the period 2005-2014.
(iv) The model uses two instruments: (1) average thickness of the oil and gas deposits in each shale play; and (2) each county's square miles with oil and gas wells in the 1980s. The geological instrument reflects the predetermined availability of oil and gas reserves whereas drilling intensity in 1980s reflects the county's history of oil and gas production.
(v) The IV model also includes a series of instruments with time interactions to avoid time-varying endogeneity bias.

Consistent with the OLS estimation, the expansion of the oil and gas sector is associated with gains for construction and extraction, installation, transportation, engineering, and office administrative occupational categories. For example, the 0.761 multiplier suggests that for every 10 jobs created in the oil and gas sector is associated with an additional 7.6 jobs in construction occupations. Occupations such as management, business, computer, social sciences, production, and legal

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[20] Appendix Tables A.4 and A.5 contain the full IV results.

[21] Our instruments appear strong based on the first-stage F-statistic of 53.05. The Hansen over-identification test p-values imply that 16 out of 19 models are well-identified. In sum, using IV with instruments based on geological and historical nature, and differencing out the county fixed effects suggest that our empirical approach is robust (though one should always exercise appropriate caution in interpreting the results).

services are no longer significantly impacted with the IV approach. Likewise, job growth in food preparation, sales, art and design, and agriculture occupation remains statistically unaffected by oil and gas expansion. For agricultural occupations, the result is similar to the findings that drilling has no impact on hired labor per farm in 2012 in the Marcellus Shale region (Hoy et al. 2018).

Job growth in healthcare, protective services, grounds maintenance, and personal care occupations are negatively affected, which indicates displacement or crowding-out due to oil and gas development. The negative effect could be due to the offsetting general equilibrium effects of the labor demand shock on wages and prices (Moretti 2010). For example, increasing in costs of hiring healthcare workers, due to labor demand shocks from oil and gas development, could cause a decline in demand for such occupations, thereby resulting in a decline in their employment. The crowding-out could also be a result of workers employed in healthcare, protective services, grounds maintenance, and personal care occupations transferring to more attractive higher paying jobs, potentially related to the oil and gas industry (Measham et al. 2019).

Likewise, occupations directly related to the oil and gas sector including construction and extraction, and transportation and material moving experience significant negative growth in counties with higher initial shares of oil and gas, while architecture and engineering, social sciences, computers, and healthcare experience positive job growth. The industry-mix growth rate has a significant positive impact on occupational job growth in: architecture and engineering; food preparation; grounds maintenance; personal care; and production.

Table 5: Major group Instrumental variable results (2-digit SOC codes)

Panel A

Dependent variable: Change in occupation-specific job growth

Variable name	Management	Business	Computer	Engineering	Social sciences
Change in oil and gas growth	0.019	0.013	-0.009	0.017**	0.006
Energy share	-0.001	0.016	0.012**	0.047***	0.027***
Change in industry mix growth rate	0.0001	0.002	0.001	0.004**	0.001
Over-identification test	0.503	0.097(N)	0.234	0.448	0.322

Panel B

Dependent variable: Change in occupation-specific job growth

Variable name	Legal	Arts & Design	Healthcare	Protective Service	Food Preparation
Change in oil and gas growth	0.003	-0.005	-0.026**	-0.038***	0.031
Energy share	0.001	-0.006	0.027*	0.048	-0.025
Change in industry mix growth rate	-0.00002	0.0005	0.001	0.0002	0.009***
Over-identification test	0.250	0.072(N)	0.198	0.28	0.267

Panel C

Variable name	Cleaning & Maintenance	Personal care	Sales	Office Admin	Agriculture
Change in oil and gas growth	-0.027**	-0.025*	0.029	0.057**	-0.035
Energy share	0.003	0.011	-0.037	-0.027	0.0180
Change in industry mix growth rate	0.005**	0.005*	0.003	0.007	-0.0002
Over-identification test	0.221	0.517	0.206	0.188	0.779

Panel D

Dependent variable: Change in occupation-specific job growth

Variable name	Construction	Installation	Production	Transportation
Change in oil and gas growth	0.761***	0.099***	0.006	0.255***
Energy share	-0.379***	-0.008	0.011	-0.171***
Change in industry mix growth rate	-0.0004	0.003	0.032***	0.005
Over-identification test	0.039 (N)	0.160	0.439	0.172

Significance: ***p<0.01, **p<0.05, and *p<0.1. Note: (i) Standard errors are clustered at BEA area level; (ii) Occupations are defined at the 2-digit 2010 Standard Occupation Classification codes (i.e. major group). (iii) Change in oil and gas employment is measured as base-period *t's* percentage change in total employment directly due to oil and gas employment growth minus its value for the preceding year *t-1*.

(iv) The dependent variable and independent variables are calculated for the period 2005-2014.

(v) See notes iv and v from Table 4 and the text for details regarding the instruments.

Overall, the results depict considerable heterogeneity in the occupational categories directly affected by oil and gas development. While it would be informative to explore which specific industries experience job growth in each occupational category, lack of industry-occupation-specific data limit our analysis to just occupations. Based on existing evidence of significant job-multiplier effects of oil and gas booms on local job growth across tradable and non-tradable industries (Marchand 2012; Tsvetkova and Partridge 2016; Weinstein 2014), we infer that there are some spillovers of oil and gas development on occupations in industries outside of oil and gas.

4.3. Human capital requirements for broad occupational groups (5-digit SOC)

Table 6 shows the job multiplier estimates for the top five major occupational categories using IV estimation.[22] Larger estimates for construction and extraction, transportation and materials moving, and installation, maintenance, and repair occupations are consistent with the high location quotients estimated by Gabe and Abel (2012). The natural advantage provided by close proximity to natural resources means these three occupations are geographically concentrated.

Table 6: Top-5 occupations based on the magnitude of oil and gas multiplier effect

Major Group	Occupation	Job multiplier estimate
47-0000	Construction & Extraction	0.761
53-0000	Transportation & Material Moving	0.255
49-0000	Installation, Maintenance, and Repair	0.099
43-0000	Office and Administrative Support	0.057
17-0000	Architecture and Engineering	0.017

Note: The job-multiplier estimates are the coefficient estimates that depict the impact of change in oil and gas employment growth on the change in the occupation-specific job growth.

For a deeper understanding of links between oil and gas development and occupations, we re-estimate *Equation 1* at the broad SOC level for the top-five occupational categories.[23] Combined

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[22] Appendix Figure A.2 presents the annual change in employment for the top-5 major occupational categories as listed in *Table 6* with values indexed at 100 in 2005. In addition, we re-estimated the models to investigate whether the Great Recession years had different local labor-market dynamics. These models only used the 2008-2009 Great Recession years and individually examined the top-5 occupations. Our unreported results suggest no statistical impact of the Recession on the oil-and-gas multiplier estimates. Given that any other year-specific impacts are already accounted for by the year fixed effects, the multiplier effects of the oil-and-gas sector on occupation-specific job growth is not (statistically) influenced by the recession. One change was that the oil and gas *employment share* variable did lose its significance, even though it maintained its directionality. Yet, that variable is not central to our analysis.

[23] Broad-group estimation narrowed down the occupations that are key for oil and gas development and allow for an

with O*NET data, estimation at this finer scale allows for an in-depth examination of the education, experience, and training requirements of each occupational category, which is essential in understanding the implications of oil and gas development on local human capital.

We find that occupations with significant positive job growth due to oil and gas development such as derrick, rotary drill, and service unit operators, and oil and gas roustabouts require less than high school education with an average of few months to a year of work experience and training. Whereas construction laborers and equipment operators, pipelayers, plumbers, pipefitters, steamfitters, truck drivers, and dredge operators, on average, have at least a high school education, and require a few months to three years of work experience and training. In addition to a high school diploma, explosives workers, extraction helpers, electricians, crane, tower and pumping-station operators, and secretaries require a post-secondary certification. These include vocational and technical training focusing on natural resource and engineering technologies, construction trades, and mechanic and repair technologies, along with at least one to five years of work experience and training. Specifically, construction and extraction supervisors are required to have, on average, five years of experience and two years of on-the-job training. Drafters, and engineers, surveyors, and mapping technicians require at least some college or an associate's degree with an average work experience of two to four years and training of over one year. Likewise, human-capital intensive occupations such as engineers and cartographers require at least a bachelor's degree and an average work experience of up to six years.

Overall, the results demonstrate a considerable variation in the jobs created due to oil and gas development. As expected, the magnitude of the effect is higher for occupations directly related to the sector. Nonetheless, the results show some spillovers on occupations in non-energy

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in-depth assessment of the human-capital requirements for those occupations. For example, Appendix Table A.7 shows how further disaggregating the construction and extraction sub-occupations reported in *Table 6* led to differential effects for the various sub-groups.

industries. A closer look at the human capital requirements reveal increasing demand for workers with varying levels of education and training. However, we find that the labor demand shock from oil and gas development leads to a significant increase in demand for workers with intermediate human capital. This corroborates Rajbhandari et al.'s (2020) findings that areas with oil and gas development experience a disproportionate increase in in-migrants with intermediate human capital. Taken together, both the labor supply and demand effects of oil and gas development provide useful insights into the impacts of oil and gas booms on local labor markets. Unlike a coal boom that is associated with an increase in demand for specifically low skilled workers, we find that oil and gas booms are associated with greater demand for a variety of human capital levels, leading to a more diverse local labor market composition.

5. Conclusion, limitations, and future extensions

Studies of the specific human capital effects of shale oil and gas shocks are relatively scarce. Most existing studies focusing on the labor market impacts of oil and gas development do not account for job types, i.e. occupations. To our knowledge, this study is the first to investigate how oil and gas booms affect occupation-specific job growth. Our findings, combined with information on average education, experience, and training requirements by occupation demonstrate a wide variation in occupational demands during oil and gas booms. This study highlights the changes in occupations in oil and gas boom regions, which could alter the region's human capital composition, and thereby, greatly influence the region's ability to respond to eventual energy busts and develop economic resilience.

We use a first-difference methodology to analyze the impact of oil and gas development across different occupational categories. To avoid potential endogeneity, we employ an IV approach that combines two instruments, namely average thickness of the shale resources and drilling intensity in the 1980s. The IV estimates indicate a significant impact of oil and gas development on occupation-specific job growth for 9 of the 19 major occupational categories. Construction and extraction categories experience the largest increase in job growth. The job multiplier estimate indicates that every 10 jobs directly created in the oil and gas sector is associated with 7.6 additional jobs in construction and extraction occupations.

Key affected occupations range from low-skilled derrick, rotary drill, and service unit operators requiring less than high school diploma and an average of a few months to a year of work experience and training, while human-capital intensive occupations such as engineers and cartographers requiring at least a bachelor's degree and average work experience of up to six years. A significant number of these occupations, on average, require workers to have vocational and technical training in addition to a high school diploma, thereby indicating an increased demand for workers with intermediate skills. This is consistent with the disproportionate labor supply response of migrants into boom areas who have similar skills (Rajbhandari et al. 2020). In sum, the labor supply and demand effects of oil and gas development and provide useful insights into the impacts of oil and gas booms on local labor markets.

Using major and broad occupational groups reduce within-occupation variation prevalent in previous studies with 1-digit SOC codes. In addition, combined with O*NET data, it allows for a deeper analysis with occupation-specific characteristics such as education, work experience, and training requirements. Since the average values for education, work experience, and training for each occupation are calculated by converting categorical data from O*NET into continuous values (Gabe and Abel 2012; Feser 2003), the measures may be noisy and should be cautiously interpreted.

Considering that the geographical patterns of occupations in the oil and gas industry are dependent on the location of the natural resources (Gabe and Abel 2012), the results suggest significant occupational job growth directly related to the oil and gas industry. Nonetheless, it is possible that there are spillovers on occupations in industries outside oil and gas (Marchand 2012; Tsvetkova and Partridge 2016; Weinstein 2014). Unfortunately, due to the lack of industry-specific occupation data, our analysis is limited to investigating job growth across occupations.[24]

Our findings have important policy implications. Greater demand for occupations requiring intermediate skills—which are likely filled by in-migrants—highlights a need for providing technical and vocational training to the local workforce. This is especially important in ensuring that the locality receives more economic benefits from oil and gas extraction. Additionally, the results indicate that some occupations experiencing significant job growth such as engineers and cartographers require highly educated individuals. Retaining such workers play an essential role in fostering long-term local economic growth (Simon and Nardinelli 2002; Glaeser and Shapiro 2003; Whisler et al. 2008). However, highly educated workers may be especially repelled by the externalities associated with energy development (Rajbhandari et al. 2020). Thus, energy boom areas need to develop strategies to retain their educated workforce. One way could be to maintain a balance between quality-of-life and environmental concerns with economic growth, which would also improve overall population growth (Kinnaman 2011; Zwickl 2019). Additionally, economic diversification could also retain some workers when the inevitable energy busts occur.

Given that occupations may share similarities and dissimilarities in the types of required knowledge, a future research avenue could investigate the degree of transferability of skills across sectors, specifically from energy to other sectors. Moreover, given the importance in understanding the welfare implications of energy booms, facilitating worker transitions between industries during energy busts would enhance resilience. Greater inter-sectoral labor mobility, especially in supporting a diversified economy, also helps retain higher skilled workers (Diodato and Weterings 2015). Additionally, further research examining substitution effects between and within

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[24] U.S. Department of Labor OES data for annual wages and employment by industry are only at the state level.

occupations, as well as between boom and non-boom counties, to account for potential spillovers, would greatly benefit the existing literature.

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Appendix

Table A.1a: Descriptive statistics: Annual Percentage Contribution of Each Occupation to the County’s Total Employment Growth. (2-digit SOC codes), 2005-2014

SOC	Occupation	Mean	Min	Max
11	Management	-.020	-50.109	187.400
13	Business & Financial Operations	.007	-8.916	14.511
15	Computer and Mathematical	.007	-4.040	7.046
17	Architecture & Engineering	.001	-6.632	10.615
19	Life, Physical, & Social Science	.005	-3.295	16.034
23	Legal	-.001	-2.185	3.502
27	Arts, Design, & Entertainment, Sports, Media.	-.004	-2.305	4.14
29	Healthcare Practitioners and Technical	.049	-9.300	8.417
33	Protective Services	.014	-11.452	17.766
35	Food Preparation and Serving	.059	-11.901	12.644
37	Building & Grounds Cleaning, Maintenance	.033	-7.697	13.958
39	Personal Care & Service	.023	-6.911	10.385
41	Sales	-.016	-16.466	8.338
43	Office & Administrative Support	.002	-10.684	16.850
45	Farming, Fishing, and Forestry	.019	-22.813	57.394
47	Construction & Extraction	-.013	-29.347	30.342
49	Installation, Maintenance, & Repair	.017	-6.543	8.305
51	Production	-.090	-14.195	20.752
53	Transportation and Material Moving	.031	-14.419	24.907

Note: (i) Each occupation in a SOC code is placed in one of 23 major groups. We focus specifically on the 19 occupations listed above based on the list by the Occupational Employment and Wage Statistics from the Bureau of Labor Statistics that are related to the oil and gas sector. (ii) Annual mean values are calculated for each occupation over the 2005-2014 period. These occupation variables are defined as the annual percentage-change in total-employment growth that is directly due to the change in the occupation’s employment. The formula is represented as $100\ \times \left(\frac{countyjobs_{iot} - countyjobs_{io(t-1)}}{totalcountyjobs_{i(t-1)}}\right)$.

(iii) The sample size is 31,090.

Table A.1b: Descriptive Statistics: The mean and standard deviations of the independent and instrumental variables

Independent Variables	Mean	Standard Deviation
Oil and gas growth rate	0.07	0.77
Energy share	.009	0.03
Industry mix growth rate	1.65	6.67
Population Density, 2000	186.9	1180.9
% Bachelor's Degree, 2000	17	7.8
Log Wage & Salary Income, 2000	12.42	1.73
Natural Amenities, 2000	3.49	1.04
Non-metro counties, 2003	0.65	0.48
Instruments		
Average thickness of shale oil and gas deposit	0.0003	0.0031
Number of square miles with oil and gas wells in the 1980s (county level)	0.0003	0.0008

Note: (i) The independent variables are calculated as included in the models.
(ii) The mean values of the independent variables are calculated for the period 2005-2014. (iii) The oil and gas employment variable is defined as the oil and gas employment growth rate relative to the total employment. The formula is represented as $\left(\frac{oilandgasemp_{it} - oilandgasemp_{it-1}}{totalcountyemp_{it-1}}\right)$
(iii) The sample size for the independent variables is 31,090 and for instrumental variables is 3,109.

Table A.2. Descriptive Statistics: Top-10 counties based on the percentage increase in total employment directly due to changes in energy employment, 2010-2014

County	2010-2014 Percent change in total employment due to the direct change in energy employment	Shale play	Population (2010)	Metro vs NM	Top in-migrant origin county
Dunn, ND	77	Bakken	3,536	NM	Stark, ND (M)
Williams, ND	62	Bakken	22,589	NM	Barry, MO (M)
McMullen, TX	55	Eagleford	711	NM	Milam, TX (M)
La Salle, TX	45	Eagleford	6,913	NM	Bexar, TX (C)
Kenedy, TX	43	Eagleford	417	NM	Taylor, TX (F)
McKenzie, ND	37	Bakken	6,412	NM	Bexar, TX (F)
Live Oak, TX	35	Eagleford	11,556	NM	Nueces, TX(C)
Shackelford, TX	33	Barnett	3,383	NM	Taylor, TX (M)
Irion, TX	30	Permian	1,607	Metro	Unita, WY (F)
Dimmit, TX	29	Eagleford	10,043	NM	Maverick, TX (C)

Note: (i) The values in Column 2 are calculated using employment data from oil and gas extraction (NAICS code: 2111) and support activities for mining (NAICS code: 2131) from 2010 to 2014. A map of the 10-counties' locations is in Figure A.3. (ii) The letters C, M, and F in column 6 refer to geographical proximity of the origin counties from which the top-10 counties receive the largest number of in-migrants. *Close (C)* – sending counties are relatively close to the receiving energy county; *Far (F)* – sending counties are far from the receiving energy county, often in different state(s). *Mixed (M)* – a mixed combination of close and far origin counties (iii) NM refers to nonmetropolitan county. We use the U.S. Census Bureau 2003 official definition of metropolitan areas. (iv) The 2010 county population is from the U.S. Census Bureau (v) A map of the shale plays in the lower 48 states is available at: https://www.eia.gov/maps/images/shale_gas_lower48.jpg.

Table A.3: Total job growth OLS estimation results [Full Results]

Variable name	Change in total job growth
Change in oil and gas growth	1.05***
Energy share	-0.27
Change in industry mix growth rate	0.074**
Population Density, 2000	0
% Bachelor's Degree, 2000	0.302***
Log Wage & Salary Income, 2000	-0.025***
Natural Amenities, 2000	0.001
Nonmetro counties, 2003	-0.068***
State & Time Fixed Effects	Yes

Significance: ***p<0.01, **p<0.05, and *p<0.1.

Note: (i) Standard errors are clustered at BEA area level.

(ii) Change in oil and gas employment is measured as base-period *t's* percentage change in total employment directly due to oil and gas employment growth minus its value for the preceding year *t-1*.

(iii) The dependent variable and independent variables are calculated for the period 2005-2014.

(iv) See notes iv and v from Table 4 and the text for details regarding the instruments.

Table A.4: Major group estimation results (2-digit SOC codes) [Full Results]

Panel A

Dependent variable: Change in occupation-specific job growth

Variable name	Management	Business	Computer	Engineering	Social sciences
Change in oil and gas growth	0.048***	0.027***	0.005***	0.038***	0.018***
Energy share	-0.017	0.008	0.005	0.035***	0.021***
Change in industry mix growth rate	-0.0001	0.002	0.001	0.004**	0.001
Population Density, 2000	0	0	0	0	0
% Bachelor's Degree, 2000	0.024*	0.024***	0.015***	0.002	0.006**
Log Wage & Salary Income, 2000	-0.001	-0.001***	0.00001	-0.0003**	-0.0001**
Natural Amenities, 2000	0.001	-0.0001	0.0001	0.0001	-0.0002**
Nonmetro counties, 2003	-0.004***	-0.002***	-0.0005*	-0.001	-0.0003
State & Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
N	30000	30000	30000	30000	30000

Panel B

Dependent variable: Change in occupation-specific job growth

Variable name	Legal	Arts & Design	Healthcare	Protective Service	Food Preparation
Change in oil and gas growth	0.007***	-0.003	0.003	0.001	-0.002
Energy share	-0.001	-0.008	0.011	0.026	-0.006
Change in industry mix growth rate	-0.00004	0.0005	0.001	0	0.009***
Population Density, 2000	0	0.000***	0.000***	0.000*	-0.000***
% Bachelor's Degree, 2000	0.003***	0.008***	0.019***	0.008***	0.062***
Log Wage & Salary Income, 2000	-0.0002***	-0.001***	-0.001***	-0.001***	0.0001
Natural Amenities, 2000	0.00001	0.0002	0.0001	0.00023	0.002**
Nonmetro counties, 2003	-0.00002	-0.001***	-0.001	-0.001*	-0.005***
State & Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
N	30000	30000	30000	30000	30000

Significance: ***p<0.01, **p<0.05, and *p<0.1.

Note: (i) Standard errors are clustered at BEA area level.

(ii) Occupations are defined at the 2-digit 2010 Standard Occupation Classification Codes (i.e. major group).

(iii) Change in oil and gas employment is measured as base-period *t's* percentage change in total employment directly due to oil and gas employment growth minus its value for the preceding year *t-1*.

(iv) The dependent variable and independent variables are calculated for the period 2005-2014.

Table A.4: Major occupation-group estimation results (2-digit SOC codes) [Full Results] (cont.)

Panel C

Dependent variable: Change in occupation-specific job growth

Variable name	Cleaning & Maintenance	Personal care	Sales	Office Admin	Agriculture
Change in oil and gas growth	0.001	0.004	0.037***	0.071***	0.0072
Energy share	-0.012	-0.005	-0.041	-0.035	-0.005
Change in industry mix growth rate	0.005*	0.005	0.003	0.007	-0.0004
Population Density, 2000	0	0	0	0	0
% Bachelor's Degree, 2000	0.017**	0.011**	0.025***	0.048***	-0.006
Log Wage & Salary Income, 2000	-0.002***	-0.0001	-0.003***	-0.003***	-0.002***
Natural Amenities, 2000	0.001**	-0.0002	-0.0001	-0.0003	-0.001***
Nonmetro counties, 2003	-0.003***	-0.003**	-0.009***	-0.007***	-0.0005
State & Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
N	30000	30000	30000	30000	30000

Panel D

Dependent variable: Change in occupation-specific job growth

Variable name	Construction	Installation	Production	Transportation
Change in oil and gas growth	0.504***	0.067***	0.051***	0.176***
Energy share	-0.239***	0.010	-0.013	-0.128*
Change in industry mix growth rate	0.001	0.003	0.031***	0.005
Population Density, 2000	0	0	-0.000***	0
% Bachelor's Degree, 2000	0.004	0.004	-0.028**	-0.007
Log Wage & Salary Income, 2000	-0.003***	-0.002***	-0.001	-0.001***
Natural Amenities, 2000	-0.001	0.00004	0.0001	-0.001
Nonmetro counties, 2003	-0.015***	-0.005***	-0.007***	-0.004***
State & Time Fixed Effects	Yes	Yes	Yes	Yes
N	30000	30000	30000	30000

Significance: ***$p<0.01$, **$p<0.05$, and *$p<0.1$.

Note: (i) Standard errors are clustered at BEA area level.

(ii) Occupations are defined at the 2-digit 2010 Standard Occupation Classification Codes (i.e. major group).

(iii) Change in oil and gas employment is measured as base-period *t's* percentage change in total employment directly due to oil and gas employment growth minus its value for the preceding year *t-1*.

(iv) The dependent variable and independent variables are calculated for the period 2005-2014.

Table A.5: Total job growth Instrumental variable results [Full Results]

Variable name	Change in total job growth
Change in oil and gas growth	1.019***
Energy share	-0.26
Change in industry mix growth rate	0.074**
Population Density, 2000	0
% Bachelor's Degree, 2000	0.302***
Log Wage & Salary Income, 2000	-0.025***
Natural Amenities, 2000	0.001
Nonmetro counties, 2003	-0.068***
State & Time Fixed Effects	Yes
Over-identification test	0.0484

Significance: ***p<0.01, **p<0.05, and *p<0.1. Note: (i) Standard errors are clustered at BEA area level; (ii) Change in oil and gas employment is measured as base-period *t's* percentage change in total employment directly due to oil and gas employment growth minus its value for the preceding year *t-1*. (iii) The dependent variable and independent variables are calculated for the period 2005-2014. (iv) See notes iv and v from Table 4 and the text for details regarding the instruments.

Table A.6: Major group Instrumental variable results (2-digit SOC codes) [Full Results]

Panel A

Dependent variable: Change in occupation-specific job growth

Variable name	Management	Business	Computer	Engineering	Social sciences
Change in oil and gas growth	0.019	0.013	-0.009	0.017**	0.006
Energy share	-0.001	0.016	0.012**	0.047***	0.027***
Change in industry mix growth rate	0.0001	0.002	0.001	0.004**	0.001
Population Density, 2000	0.000	0.000	0.000	-0.000	-0.000
% Bachelor's Degree, 2000	0.024*	0.024***	0.015***	0.002	0.006**
Log Wage & Salary Income, 2000	-0.001	-0.001***	-0.000	-0.0003**	-0.0002**
Natural Amenities, 2000	0.0001	-0.0001	0.0001	0.0001	-0.0001*
Nonmetro counties, 2003	-0.004***	-0.002***	-0.0005*	-0.0007*	-0.0003
State & Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Over-identification test	0.503	0.097(N)	0.234	0.448	0.322

Panel B

Dependent variable: Change in occupation-specific job growth

Variable name	Legal	Arts & Design	Healthcare	Protective Service	Food Preparation
Change in oil and gas growth	0.003	-0.005	-0.026**	-0.038***	0.031
Energy share	0.001	-0.006	0.027*	0.048	-0.025
Change in industry mix growth rate	-0.00002	0.0005	0.001	0.0002	0.009***
Population Density, 2000	0.000	0.000***	0.000***	0.000*	-0.000***
% Bachelor's Degree, 2000	0.003***	0.008***	0.019***	0.008***	0.062***
Log Wage & Salary Income, 2000	-0.0002***	-0.001***	-0.001***	-0.001***	0.0002
Natural Amenities, 2000	0.00002	0.0002	0.0002	0.0004	0.001**
Nonmetro counties, 2003	-0.00002	-0.001***	-0.001	-0.001**	-0.005***
State & Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Over-identification test	0.250	0.072(N)	0.198	0.28	0.267

Significance: ***$p<0.01$, **$p<0.05$, and *$p<0.1$. Note: (i) Standard errors are clustered at BEA area level; (ii) Occupations are defined at the 2-digit 2010 Standard Occupation Classification codes (i.e. major group). (iii) Change in oil and gas employment is measured as base-period *t's* percentage change in total employment directly due to oil and gas employment growth minus its value for the preceding year *t-1*.

(iv) The dependent variable and independent variables are calculated for the period 2005-2014.

(v) See notes iv and v from Table 4 and the text for details regarding the instruments.

Table A.6: Major group Instrumental variable results (2-digit SOC codes) [Full Results] (cont.)

Panel C

Variable name	Cleaning & Maintenance	Personal care	Sales	Office Admin	Agriculture
Change in oil and gas growth	-0.027**	-0.025*	0.029	0.057**	-0.035
Energy share	0.003	0.011	-0.037	-0.027	0.0180
Change in industry mix growth rate	0.005**	0.005*	0.003	0.007	-0.0002
Population Density, 2000	-0.000	0.000	0.000	0.000	0.000
% Bachelor's Degree, 2000	0.017**	0.011***	0.025***	0.048***	-0.006
Log Wage & Salary Income, 2000	-0.002***	-0.0001	-0.003***	-0.003***	-0.002***
Natural Amenities, 2000	0.001**	-0.0001	-0.0001	-0.0002	-0.001**
Nonmetro counties, 2003	-0.003***	-0.003**	-0.009***	-0.007***	-0.001
State & Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Over-identification test	0.221	0.517	0.206	0.188	0.779

Panel D

Dependent variable: Change in occupation-specific job growth

Variable name	Construction	Installation	Production	Transportation
Change in oil and gas growth	0.761***	0.099***	0.006	0.255***
Energy share	-0.379***	-0.008	0.011	-0.171***
Change in industry mix growth rate	-0.0004	0.003	0.032***	0.005
Population Density, 2000	0.000	-0.000	-0.000***	-0.000
% Bachelor's Degree, 2000	0.004	0.004	-0.028**	-0.007
Log Wage & Salary Income, 2000	-0.003***	-0.002***	-0.001	-0.001***
Natural Amenities, 2000	-0.001	-0.00002	0.0002	-0.001
Nonmetro counties, 2003	-0.014***	-0.005***	-0.008***	-0.004***
State & Time Fixed Effects	Yes	Yes	Yes	Yes
Over-identification test	0.039 (N)	0.160	0.4389	0.1717

Significance: ***p<0.01, **p<0.05, and *p<0.1. Note: (i) Standard errors are clustered at BEA area level; (ii) Occupations are defined at the 2-digit 2010 Standard Occupation Classification codes (i.e. major group). (iii) Change in oil and gas employment is measured as base-period *t's* percentage change in total employment directly due to oil and gas employment growth minus its value for the preceding year *t-1*.

(iv) The dependent variable and independent variables are calculated for the period 2005-2014.

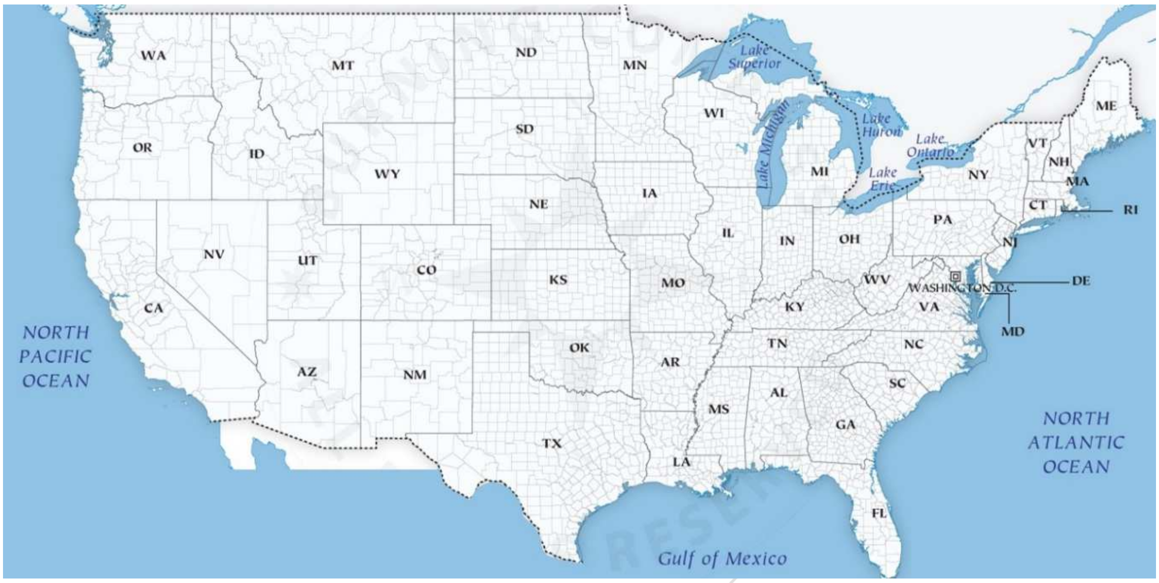
(v) See notes iv and v from Table 4 and the text for details regarding the instruments.

Table A.7: Construction and Extraction major and broad occupational categories (47-0000)

Major	**Minor**	**Broad**	**Name**
47-0000			**Construction and Extraction Occupations**
	47-1000		*Supervisors of Construction and Extraction Workers*
		47-1010	First-Line Supervisors of Construction Trades and Extraction Workers
	47-2000		Construction Trades Workers
		47-2010	Boilermakers
		47-2020	Brickmasons, Blockmasons, and Stonemasons
		47-2030	Carpenters
		47-2040	Carpet, Floor, and Tile Installers and Finishers
		47-2050	Cement Masons, Concrete Finishers, and Terrazzo Workers
		47-2060	Construction Laborers
		47-2070	Construction Equipment Operators
		47-2080	Drywall Installers, Ceiling Tile Installers, and Tapers
		47-2110	Electricians
		47-2120	Galziers
		47-2130	Insulation Workers
		47-2140	Painters and Paperhangers
		47-2150	Pipelayers, Plumbers, Pipefitters, and Steamfitters
		47-2160	Plasterers and Stucco Masons
		47-2170	Reinforcing Iron and Rebar Workers
		47-2180	Roofers
		47-2210	Sheet Metal Workers
		47-2220	Structural Iron and Steel Workers
		47-2230	Solar Photovoltaic Installers
	47-3000		*Helpers, Construction Trades*
		47-3010	Helpers, Construction Trades
	47-4000		*Other Construction and Related Workers*
		47-4010	Construction and Building Inspectors
		47-4020	Elevator Installers and Repairers
		47-4030	Fence Erectors
		47-4040	Hazardous Materials Removal Workers
		47-4050	Highway Maintenance Equipment Operators
		47-4060	Rail-Track Laying and Maintenance Equipment Operators
		47-4070	Septic Tank Servicers and Sewer Pipe Cleaners
		47-4090	Miscellaneous Construction and Related Workers
	47-5000		*Extraction Workers*
		47-5010	Derrick, Rotary Drill, and Service Unit Operators, Oil, Gas, and Mining
		47-5020	Earth Drillers, Except Oil and Gas
		47-5030	Explosives Workers, Ordinance Handling Experts, and Blasters
		47-5040	Mining Machine Operators
		47-5050	Rock Splitters, Quarry
		47-5060	Roof Bolters, Mining
		47-5070	Roustabouts, Oil and Gas
		47-5080	Helpers – Extraction Workers
		47-5090	Miscellaneous Extraction Workers

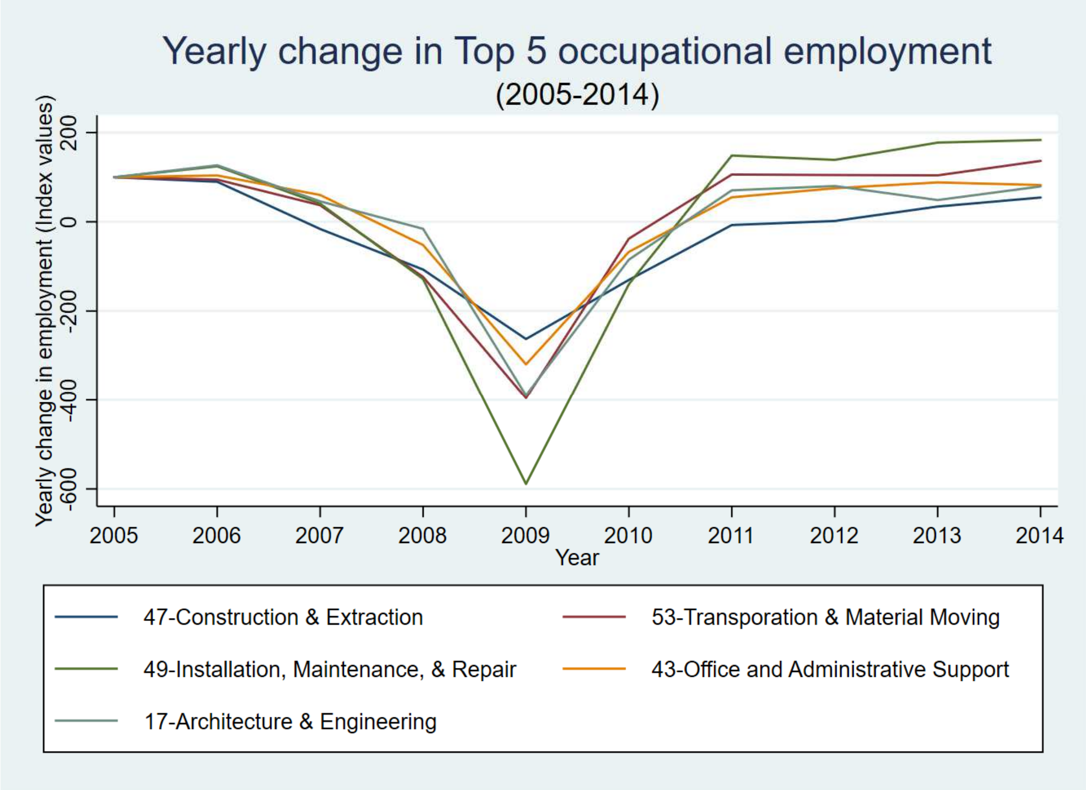
Figures

Figure A.1: Counties in the 48 Contiguous US States



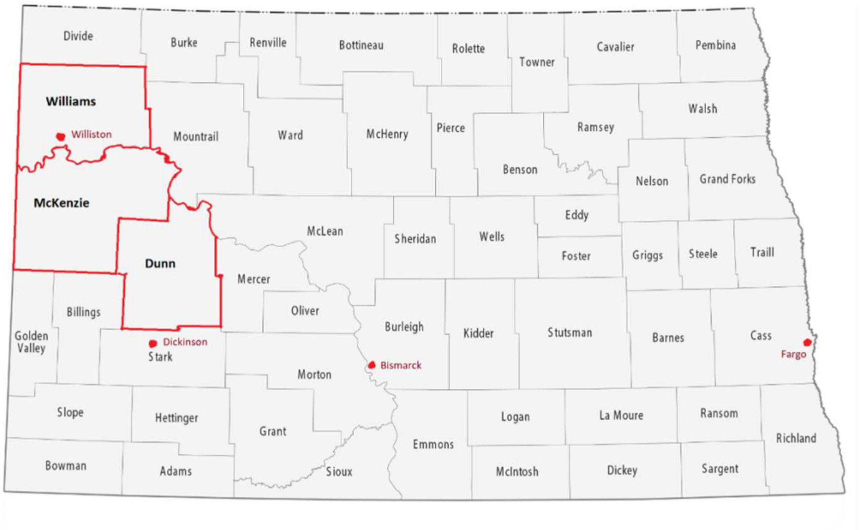
Source: https://www.burningcompass.com/countries/united-states/us-county-map.html

Figure A.2: Annual change in employment for the Top-5 occupational categories



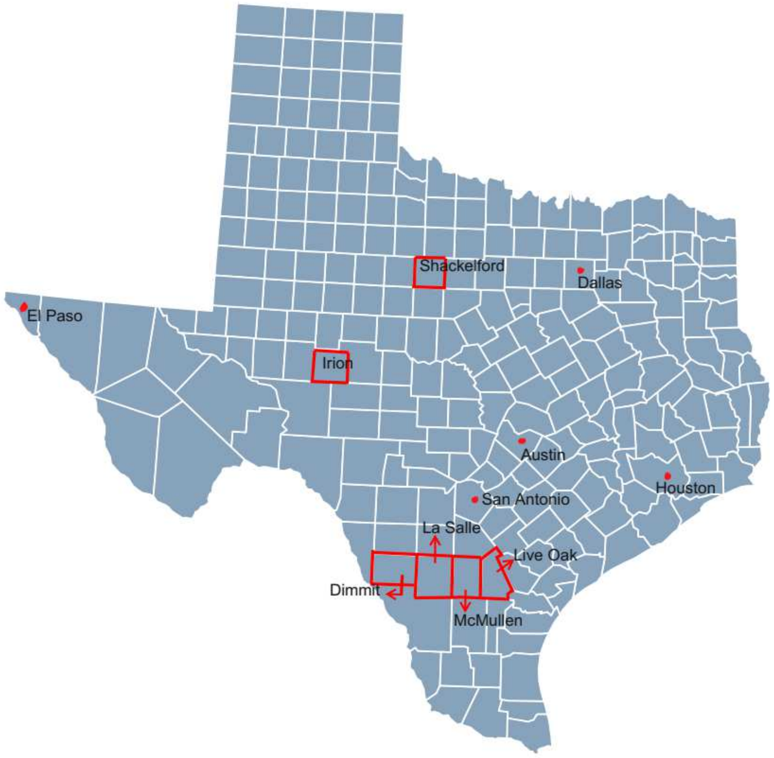
Note: (i) The values are calculated for the top-5 major occupational categories as listed in Table 6.
(ii) Annual change in employment values for all 5 major-occupation categories in 2005 are indexed at 100.

Figure A.3a: Counties in North Dakota with the highest total employment growth directly as a result of energy employment, 2010-2014 (From Table A.2) and major cities.



Source: https://gisgeography.com/north-dakota-county-map/

Figure A.3b: Counties in Texas with the highest total employment growth directly as a result of energy employment, 2010-2014 (From Table A.2) and major cities.



Source: https://imis.county.org/iMIS/CountyInformationProgram/TexasMapCIP.aspx