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DISCUSSION PAPER SERIES

IZA DP No. 12619

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John V. Winters
Iowa State University and IZA

Zhengyu Cai
Southwestern University of Finance and Economics

Karen Maguire
Oklahoma State University

Shruti Sengupta
Oklahoma State University

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IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Do Workers Benefit from Resource Booms in Their Home State? Evidence from the Fracking Era

Fracking innovations revolutionized the United States oil and gas industry and facilitated a boom in energy production in states with oil and gas resources. This paper examines effects of oil and gas booms within a state on individual employment and earnings. To account for endogenous migration decisions, we instrument for oil and gas production in workers' state of residence via the predicted percent of oil and gas employment in their state of birth. We find statistically significant and economically meaningful positive effects. The bulk of the effects accrue to workers employed outside the oil and gas industry indicating sizable spillovers.

JEL Classification: J20, J30, Q40, R10

Keywords: resource boom, regional economic development, employment, wages, income

Corresponding author:
John V. Winters
Iowa State University
Department of Economics
460B Heady Hall
518 Farm House Lane
Ames, IA, 50011-1054
USA
E-mail: winters1@iastate.edu

1. Introduction

Technological innovations have transformed the oil and gas industry in the United States beginning in the mid-2000s. Advancements in horizontal drilling and hydraulic fracturing provided greater access to oil and gas in shale plays that were previously unprofitable to develop (Weber 2012; Munasib and Rickman 2015; Feyrer, Mansur, and Sacerdote 2017; Upton and Yu 2017; Kearney and Wilson 2018). A rise in global energy prices post 2000 accelerated the use of the higher cost fracking technology and caused U.S. oil and gas production to soar. Oil and gas employment in the United States boomed and peaked in 2014, before receding in subsequent years following a drop in world oil prices. Oil and gas resources, including those in shale plays, are geographically concentrated, and the employment gains in the oil and gas industry have been unequal across areas. The effects of oil and gas development on state and local economies is an important issue, but there is uncertainty in the net benefits (Michaels 2010; Weber 2012; Munasib and Rickman 2015; Paredes et al. 2015; Marchand and Weber 2018; Cai, Maguire, and Winters 2019). On the one hand, increased oil and gas development in an area may create multiplier effects for other industries as oil and gas workers, firms, and royalty recipients spend money on locally produced goods and services (Marchand 2012; Feyrer, Mansur, and Sacerdote 2017). On the other hand, increased oil and gas development may bid up local wages and other input prices and make it more difficult for other export industries in the local area to compete in global markets.[1] Additionally, the direct effects of increased oil and gas employment may not flow to local residents if they lack needed skills for oil and gas production. Instead, many of the new oil and gas jobs may be taken by recent in-migrants, temporary residents, and long-distance

[1] Allcott and Keniston (2018) find that overall manufacturing employment is not crowded out by oil and gas booms, but there is a reallocation within manufacturing toward local sub-sectors and away from traded sub-sectors.

commuters (Green et al. 2017; Wilson 2018). Furthermore, such workers may spend only a small portion of their incomes in the local economy and instead send money to their home area.

The current study contributes to this important literature by estimating causal effects of oil and gas employment booms within a state on the work and incomes of state residents using microdata from the pooled 2001-2017 American Community Survey (ACS).[2] This includes the period of the oil and gas boom in the United States from the mid-2000s through 2014. While oil and gas resource locations are pre-determined, worker migration decisions are not. Workers are expected to respond to oil and gas shocks by migrating toward areas experiencing positive shocks and away from areas experiencing negative shocks, so ordinary least squares (OLS) estimates are potentially biased. The current study instruments for an individual's exposure to oil and gas development in their state of residence using oil and gas employment in their birth state. Our two-stage least squares (2SLS) models also include controls for individual demographic characteristics, birth-state fixed effects, and region-year fixed effects.

Our estimates indicate sizable and statistically significant positive effects of oil and gas employment in a state on the employment and incomes of individuals in the state. These results are qualitatively robust to numerous alternative specifications such as excluding oil and gas industry workers. The implication is that the oil and gas boom on average had positive net effects on state labor markets and much of the effect was through income spillovers to other industries. Of course, oil and gas development involves numerous environmental concerns, both locally and globally (Stern 2008; Muehlenbachs et al. 2015; Bartik et al. 2017; Maguire and Winters 2017). We do not assess environmental effects on welfare. Additionally, we estimate short- and

[2] In a related study, Cai, Maguire, and Winters (2019) use the 2000 Census and 2001-2016 ACS to examine effects of local oil and gas employment on individual employment and earnings for local residents in Texas. However, that study focuses on a single state, uses a very different identification strategy, and does not account for potentially endogenous migration.

medium-run labor market impacts, which may differ significantly from long-run effects (Jacobsen and Parker 2016). Increased oil and gas production is also likely to lower energy prices and increase welfare for energy users (Hausman and Kellogg 2015). We do not assess whether increased oil and gas development has an overall net positive effect on welfare. Instead, we assess state labor market impacts, which are important considerations in the broader discussion surrounding oil and gas development.

While previous literature has examined impacts of oil and gas employment on state and local labor markets, we believe ours is the first such study to implement an instrumental variables identification strategy using oil and gas employment in an individual's birth state.[3] Previous studies on this topic have found positive local spillover effects from oil and gas development on incomes in other industries, but they were unable to control for endogenous migration decisions that may affect the implications of their findings (Feyrer, Mansur, and Sacerdote 2017; Allcott and Keniston 2018; Kearney and Wilson 2018; Cai, Maguire, and Winters 2019). Workers with skills that benefit from oil and gas development may migrate to areas experiencing oil and gas development. For these workers, the oil and gas boom is not an exogenous shock, but rather an endogenous choice, potentially biasing the estimated effects on employment and income.[4] Our two stage least squares (2SLS) identification strategy allows us to determine the exogenous effects of the oil and gas boom by using a birth state instrument. As opposed to state of residence, workers do not choose their birth state and it provides an exogenous source of variation. Therefore, this study thus makes a novel contribution to an

[3] A few previous studies have used birth state instruments to examine other topics including Ciccone and Peri (2005), Black, Kolesnikova, and Taylor (2014), Lindley and Machin (2014), and Orrenius and Zavodny (2015).
[4] Our study also contributes to a broader literature examining how the impacts of regional economic shocks are distributed between prior residents and recent in-migrants (Topel 1986; Bartik 1991; Notowidigdo 2011; Yagan 2019)

important and well-studied topic. Our state-level analysis also has the advantage of internalizing intra-state spillovers missed by looking at small local areas. Feyrer, Mansur, and Sacerdote (2017) indicate that fracking impacts on wage income spill over to neighboring counties in magnitudes three times that of the wage income effects for the county where production occurs. The detailed microdata and large samples in the ACS also allow us to estimate effects by sex and age group to provide a richer understanding. In particular, we find that impacts on employment and income are larger for men than women and larger for younger workers than older ones.

2. Empirical Framework

This study uses microdata from the 2001-2017 American Community Survey and the 2000 U.S. decennial census (5% PUMS) obtained from IPUMS-USA (Ruggles et al. 2018). Our analysis is restricted to persons born in and residing in the United States at the time of the survey, not in group quarters, and ages 18-61. The data include individual information on age, sex, race, education, employment, income, industry, and other variables.

We estimate linear regression models of the form:

$$Y_{ist} = \theta PctEmpOilGas_{st} + \beta X_{ist} + \gamma_s + \delta_{st} + \varepsilon_{ist}$$

We examine four dependent variables (Y_{ist}) measuring work and income for observation i in state s and year t. Our explanatory variable of interest is $PctEmpOilGas_{st}$, the percent of employment in oil and gas for state s and year t.[5] X_{ist} includes detailed dummy control variables for sex, age, and six race/ethnicity groups. Our regressions also include state fixed effects (γ_s)

[5] It is not possible to separate employment in the oil industry from employment in the natural gas industry; the two are often produced from the same well. We also do not differentiate between the type of drilling done, e.g., conventional vs. fracking.

and census region-year fixed effects (δ_{st}). ε_{ist} is a mean zero error term. We use individual survey weights in our regressions, and standard errors are clustered by state.

Our first dependent variable is an indicator for whether an individual worked at all during the year. Our second dependent variable is estimated log annual hours worked. The third is estimated log real hourly earnings (in $2017). The fourth is log real annual earnings (in $2017). The second and third dependent variables are estimated because beginning in 2008 the ACS only reports how many weeks per year an individual worked in intervals. We use the observed relationships between the weeks worked intervals and the precise number of weeks worked in the 2001-2007 ACS to predict weeks worked. Specifically, we compute the mean weeks worked in 2001-2007 for each combination of sex, age, race/ethnicity group, and weeks worked interval; we then use those means to impute weeks worked for all years. We then multiply imputed weeks worked by usual hours worked per week to obtain estimated annual hours worked for each individual. We then convert this to logs to produce our second dependent variable. We estimate hourly earnings by dividing real annual earned income by estimated annual hours worked; converting this to logs yields our third dependent variable. Note that the last three dependent variables are constructed such that

$$AnnualEarnings = AnnualHoursWorked \times HourlyWage$$

and

$$\ln(AnnualEarnings) = \ln(AnnualHoursWorked) + \ln(HourlyWage) \quad .$$

Thus, for our linear regression models, the effects of $PctEmpOilGas_{st}$ on our second and third dependent variables will add up to the effect on the fourth dependent variable, subject to rounding error. This identity allows us to assess the contributions of hours worked and hourly earnings to effects on annual incomes. The regressions corresponding to the last three outcomes are in logs and are therefore restricted to persons with positive values for hours worked, hourly earnings, and annual earnings, respectively.

We start by estimating Ordinary Least Squares (OLS) regressions using explanatory variables for an individual's state of residence, r. Then we estimate a second OLS specification using explanatory variables for an individual's birth state, b.[6] Workers move toward areas experiencing positive labor market shocks, and migrants likely differ from prior residents in skills and labor market attachment, so OLS using explanatory variables based on state of residence is unlikely to produce unbiased causal estimates. Additionally, because many people move away from their birth states, birth state explanatory variables can measure the treatment from economic shocks with error and lead to OLS coefficient estimates attenuated toward zero. We estimate a third OLS specification that restricts the sample to persons who reside in their birth state during the ACS, which eliminates measurement error, but still may be affected by endogenous migration decisions in response to economic shocks in birth states.

To construct the treatment variables, we first use information on where individuals work, because states of residence/birth and work are different for some individuals. We calculate the percent of employment in oil and gas in each work-state, w, and we then match this measure to each individual's states of residence and birth. Specifically, we define the percent of employment in oil and gas in work-state w in year t as:

$$PctEmpOilGas_{wt} = 100 \times \frac{Oil\ and\ Gas\ Employment_{wt}}{Total\ Employment_{wt}}$$

where $Oil\ and\ Gas\ Employment_{wt}$ is the number of persons employed in the oil and gas industry in work-state w and year t and $Total\ Employment_{wt}$ is the number of persons

[6] This includes both the explanatory variable of interest and the fixed effects. That is, the first specification includes state of residence fixed effects, but the second specification includes state of birth fixed effects. Similarly, region-year fixed effects are based on region of residence and region of birth, respectively.

employed in any industry in work-state w and year t. We then link $PctEmpOilGas_{wt}$ to individual observations by year t and their state of current residence r and birth b to measure the percent of employment in oil and gas in one's state of residence, $PctEmpOilGas_{rt}$, and birth state, $PctEmpOilGas_{bt}$. An individual living in their birth state will have equal values for $PctEmpOilGas_{rt}$ and $PctEmpOilGas_{bt}$, but birth-state out-migrants will generally have different values for these two measures.

Our preferred estimates are produced using two-stage least squares (2SLS). The 2SLS regressions instrument for the percent of oil and gas employment in one's state of residence using an instrument measuring the *predicted* percent of oil and gas employment in one's birth state. We first compute:

$$PredictedPctEmpOilGas_{wt} = 100 \times \frac{Oil\ and\ Gas\ Employment_{wt}}{PredictedTotalEmployment_{wt}}$$

, which is similar to $PctEmpOilGas_{wt}$ except that the denominator is computed as:

$$PredictedTotalEmployment_{wt} = Total\ Employment_{w,2000} \times \frac{NationalTotalEmployment_{t}}{NationalTotalEmployment_{2000}}.$$

That is, the denominator in $PredictedPctEmpOilGas_{wt}$ is predicted by multiplying the total employment in work-state w in year 2000 by the ratio of national total employment in years t and 2000. Namely, the denominator, $PredictedTotalEmployment_{wt}$, is predicting total employment in work-state w and year t based on national employment growth since 2000.

$PredictedPctEmpOilGas_{wt}$ is constructed this way because changes in oil and gas employment in work-state w and year t are expected to affect total employment in work-state w and year t both directly and indirectly via multiplier effects, making dividing by actual total employment potentially endogenous. $PredictedPctEmpOilGas_{wt}$ is then matched to individuals by year and birth-state to form the instrument, $PredictedPctEmpOilGas_{bt}$. We also conduct robustness checks that instrument for the percent of oil and gas employment in one's residence state using the *actual* percent of oil and gas employment in one's birth state.

Our 2SLS specification includes birth state fixed effects and birth-region-year fixed effects.[7] Including birth state fixed effects controls for time-invariant differences in employment and income outcomes connected to place of birth. Thus, identifying variation comes from differences over time within birth states. The birth-region-year fixed effects account for aggregate economic shocks at the region-year level, so we are ultimately comparing birth states within the same census region.

In order for our 2SLS models to yield consistent estimates, the instrument should be both correlated with $PctEmpOilGas_{rt}$ in the first-stage and uncorrelated with the error term in the second stage. We argue that both conditions should hold. In particular, 64 percent of individuals in our sample reside in their birth state, so we expect a strong positive correlation between the predicted percent of oil and gas employment in one's birth state and the percent of oil and gas employment in one's state of residence. Ideally, we would have a more detailed migration history including place of birth within a state, but the ACS has limited information on prior location. The state of birth is the best such information available. Many people leave their birth state early in life and are minimally affected by subsequent economic conditions in their birth-state. Our 2SLS identification strategy, which estimates local average treatment effects, is driven by the sub-sample of observations who reside in their birth state during the ACS. We report first-stage F-statistics for our main 2SLS models below.

[7] State (and region) of residence is potentially endogenous, so state of residence fixed effects and residence region-year fixed effects are not included in our preferred models. However, we do discuss robustness checks below for the 2SLS models that include fixed effects based on both birth and residence state.

The 2SLS identification strategy and our chosen instrument address potential endogeneity concerns. Oil and gas employment in a state and year is driven by labor demand fluctuations. During the study period, several states experienced significantly increased demand for oil and gas labor due to new technologies and rising energy prices that made it profitable to increase oil and gas extraction, especially in shale plays. The geographic distribution of oil and gas deposits was determined long ago, but the economic value of those deposits changed considerably post 2000. Furthermore, the fracking revolution was unexpected. Most importantly, our instrument is the predicted percent of employment in oil and gas in an individual's birth state. Birth-states are not chosen by the individual and are determined before the fracking boom and study period. Thus, individuals were differentially exposed to oil and gas booms because they were born in different states and observed at different times. Our 2SLS models include birth-state fixed effects and exploit changes over time within birth states.

Our state-level analysis has the advantage of internalizing intra-state externalities and capturing in-state multiplier effects. Furthermore, state governments play a central role in tax and regulatory policy for the oil and gas industry in their jurisdiction, so it is particularly important to understand the state-level effects of oil and gas employment on employment and income of workers in the state. Although there is potential heterogeneity across areas within states that we cannot model, the likely employment spillovers across local areas within a state would be difficult to accurately model with instrumental variables even if we had more detailed geographic data on place of birth.

Notably, our models include detailed dummy control variables for sex, age, and six race/ethnicity groups, but we do not include in our preferred models controls for variables that individuals choose such as education, marital status, or parenthood. This is because these choice variables are likely influenced by oil and gas booms (Cascio and Narayan 2015; Rickman et al. 2017; Kearney and Wilson 2018) in ways that make them endogenous control variables. In the language of Angrist and Pischke (2009), these would be "bad controls" (pp. 64 – 68). However, we do report robustness checks below that include controls for education, marital status, and having children.

Sample means for our main variables are in Table 1; annual hours worked, hourly earnings, and annual earnings are reported in levels rather than logs for ease of interpretation. Column 1 is for the full sample, and Columns 2 and 3 split the sample based on birth state into 9 high oil and gas states and the 41 other states and DC since oil and gas booms are characterized by significant regional disparity. High oil and gas states are defined as the nine states that had oil and gas employment in 2014 greater than or equal to one percent of their total employment. These states include Alaska, Colorado, Louisiana, New Mexico, North Dakota, Oklahoma, Texas, West Virginia, and Wyoming. Figure 1 illustrates the time trend for oil and gas industry employment as a percentage of total employment for the two groups of states during 2000-2016. The high oil and gas states have lower means in Table 1 for working at all during the year, hourly earnings, and annual earnings, though mean annual hours worked are slightly higher in high oil and gas states. As expected, persons born in high oil and gas states have a higher percent of oil and gas employment in their state of residence than persons born in other states. However, the difference between Columns 2 and 3 in the percent of employment in oil and gas is smaller by state of residence than by birth state, which is also expected since many people move away from their birth state including some people moving from high oil and gas states to low oil and gas states and vice versa.

3. Empirical Results

3.1 Main Results

Table 2 presents results for the three OLS specifications in Panels A, B, and C. Panel A presents results using residence state explanatory variables, and Panel B uses birth state explanatory variables. Panel C provides OLS results for the sub-sample of individuals who live in their birth state during the ACS. Our preferred 2SLS specification results are in Panel D. Results for our four dependent variables are in Columns 1-4, respectively. We present regression results only for the main explanatory variable of interest, but all specifications include the detailed control variables and fixed effects.

OLS results in Panels A, B, and C all suggest positive and statistically significant effects of the percent of oil and gas employment on the four outcomes measuring employment and earned income. The magnitudes do vary somewhat across the OLS specifications, but the implications are qualitatively similar. For each outcome, OLS coefficient estimates are largest in Panel C and smallest in Panel B. Finding smaller coefficients in Panel B than C is consistent with birth state out-migration inducing classification error in the treatment for Panel B; Panel B estimates correspond to intent-to-treat effects. Panel C estimates correspond to average effects of treatment on the treated. However, because birth state residence is potentially affected by the treatment, our preferred estimates use 2SLS.

We report first-stage F-Statistics for the 2SLS specifications in Panel D that cluster by birth state. The F-Statistics well exceed 10 in all four columns, allowing us to rule out weak instrument concerns (Angrist and Pischke 2009; Andrews et al. 2018). The first-stage specification is the same in the four columns, but the F-statistics vary slightly because the samples in Columns 2-4 exclude observations with non-positive hours worked, hourly earnings, and annual earnings, respectively. Additionally, the first-stage coefficients on the instrument are all significantly positive as expected; they all equal 0.54 but are omitted from the table to conserve space.

The 2SLS coefficient estimates in Panel D are all positive and statistically significant at the one percent level.[8] These results are quite similar to OLS results for birth state residents in Panel C because our 2SLS identification strategy is driven by the sub-sample of observations who reside in their birth state during the ACS. The estimates in Column (1) of Panel D suggest that increasing the percent of employment in oil and gas by one (e.g. from 1.0 to 2.0) increases the probability of any work during the year by 1.4 percentage points (e.g. from 0.800 to 0.814), which is a meaningful effect. The dependent variables in Columns (2) – (4) are all in natural logs, so we can interpret small changes as percentage changes. Increasing the percent of employment in oil and gas by one increases annual hours by 2.4 percent, hourly earnings by 4.8 percent and annual earnings by 7.2 percent. To put this in context, the weighted mean among the 9 high energy states for the percent of employment in oil and gas increased from 1.32 in 2000 to 2.77 in 2014. This corresponds to 2.0 percentage points higher annual employment, 3.5 percent higher annual hours worked, 7.0 percent higher hourly wages, and 10.4 percent higher annual earnings. These are large but believable magnitudes. Furthermore, oil and gas employment fell after 2014, wiping out more than half of the 2000-2014 gains.

3.2 Sensitivity Analysis

[8] We also estimated p-values for the main results using the wild cluster bootstrap procedure proposed by Cameron, Gelbach, and Miller (2008) using the boottest Stata command discussed in Roodman et al. (2019). The p-value estimates were consistently less than 0.01.

Table 3 presents results for several important sensitivity checks for our 2SLS specification. Panel A excludes workers employed in the oil and gas industry from the regression sample. Effect magnitudes decrease slightly but not substantially compared to the preferred estimates in Table 2 Panel D. This indicates that positive effects on work and income are not just driven by direct effects of more workers gaining high-paying jobs in the oil and gas industry. Instead, there are sizable benefits accruing to workers in other industries via multiplier effects. Of course, some workers do get high-paying oil and gas jobs, so the best approach to measure overall effects is to include oil and gas workers as in Table 2 Panel D.

Panel B of Table 3 excludes persons born in six states with consistently high employment in oil and gas: Alaska, Louisiana, New Mexico, Oklahoma, Texas, and Wyoming. These six states had the highest percent of employment in oil and gas in 1980, 1990 and 2000, and they comprise six of the seven highest states in 2014, with North Dakota ranking second in 2014. Coefficient estimates in Panel B are slightly smaller in Columns 1-2 and moderately larger in Columns 3-4 compared to the preferred full sample estimates. These results indicate that the positive effects are not just driven by traditional high oil and gas states. States with less history in oil and gas also experience benefits. Panel C pushes this further by excluding persons born in the nine states with the highest percent of employment in oil and gas in 2014. Overall, the coefficient estimates in Panel C are moderately larger than the preferred full sample results in Panel D of Table 2 and less precisely estimated. Panel D excludes ACS years 2008-2012 to examine if the Great Recession and slow recovery had a disproportionate impact; results are very similar to those for the full sample.

Panel E adds a control variable for oil and gas non-labor gross domestic product (GDP) per capita in an individual's birth state in year t. This is constructed from Bureau of Economic

Analysis (BEA) data by subtracting oil and gas industry employee compensation from oil and gas industry GDP by state and year and dividing by state population; this residual captures oil and gas royalties and firm profits. The percent of employment in oil and gas is our primary measure of oil and gas development in a state, but royalties and firm profits may create multiplier effects for other industries even beyond effects of oil and gas employment. Results in Panel E are qualitatively similar to our preferred specification. Coefficient estimates in Columns 1 and 2 are slightly reduced; coefficient estimates in Columns 3 and 4 are slightly increased.

Panel F adds a shift-share predicted employment control variable similar to an approach common in previous literature (Bartik 1991; Katz and Murphy 1992). This variable is constructed by first computing industry-specific employment in each state in year 2000 and then multiplying the initial industry employment by the national industry employment growth over time and summing over industries (except for oil and gas) for each state and year. We then compute predicted log employment in an individual's birth state in year t and include it as a control variable. Results in Panel F are similar to the preferred specification, though coefficient estimates are slightly smaller. However, supply linkages are expected to cause industries that are very complementary to oil and gas to collocate in previous oil and gas areas, so this variable may inappropriately control for the growth of complementary industries and is excluded from our preferred specification.

Panel G of Table 3 adds indicator control variables for individual education, marital status, and children present. Specifically, we include 14 indicator variables for highest education completed, one indicator variable for being married, four indicator variables for number of children in the household, and six indicator variables for age of the youngest own child in the household. These additional control variables depend on individual choices likely influenced by economic conditions in a state, so our preferred specification excludes them. Still, it is useful to know that adding these additional control variables yields coefficient estimates in Panel G that are similar to though slightly larger than the preferred estimates. Panel H adds state and region-year fixed effects based on current residence; these regressions also include the birth state and birth-region-year fixed effects. Panel H results are similar to the preferred specification.

We also conduct additional sensitivity analysis with results in appendix Tables A1 and A2. We show in Table A1 that 2SLS estimates for similar alternative outcome measures provide similar conclusions. Columns 1 and 2 have dependent variables measuring working during the prior week and log weekly hours, respectively. Both are significantly positively affected by the percent of employment in oil and gas. Column 3 takes an alternative approach to examining predicted "hourly" earnings given that we do not have actual weeks worked to compute hourly earnings. Instead of imputing weeks worked as done for hourly earnings in the rest of the paper, Column 3 of Table A1 uses log annual earnings as the dependent variable but adds right-hand side controls for log weekly hours worked and dummies for the weeks worked intervals; results are qualitatively similar to Column 3 in Panel D of Table 2. Column 4 of Table A1 attempts to provide a comprehensive assessment of effects on annual earnings incorporating transitions between non-work and work by examining the log of mean annual earnings (including zero-earners) at the state-year level as the dependent variable. The Table A1 Column 4 coefficient is moderately larger than that in Table 2 Panel D.

Table A2 shows that OLS using residence-state measures for birth-state out-migrants yields positive coefficients, but coefficients are meaningfully smaller than corresponding estimates for birth-state residents in Panel C of Table 2. Migrants and their destinations are not randomly selected, so these results should be interpreted with caution. Table A2 also shows that the main results are robust to using the *actual* percent of employment in oil and gas in one's birth state as the instrument instead of the *predicted* percent of employment in oil and gas in one's birth state. Table A2 also reports 2SLS results that include state-specific linear time trends; coefficient estimates are not significantly different from the preferred estimates, though the point estimates are somewhat smaller. As shown in Figure 1, the oil and gas employment shock generally increased over time until 2014, so state-specific time trends may partially capture treatment effects and are thus not the preferred specification.

3.3 Effects over Time

We next explore effects over time. Unfortunately, ACS data are not ideal for examining the impulse responses from oil and gas shocks to state labor markets because we have only annual data. Table 4 presents IV regressions that simultaneously include five variables for the percent of employment in oil and gas in years t, $t-1$, $t-2$, $t-3$, and $t-4$. We estimate first-stage regressions for each of these variables with corresponding instruments for the predicted percent of employment in oil and gas in an individual's birth state in years t, $t-1$, $t-2$, $t-3$, and $t-4$. Including lags requires us to drop observations from the early ACS years. Still, it is informative that the effects in period t are significantly positive and largely comparable to the main estimates in Table 2 Panel D. Interestingly, there are significant negative effects on any work from $t-3$ and log annual hours worked from $t-2$, which may reflect intertemporal substitution of work for some workers. There are positive effects from $t-4$ on log hourly earnings and log annual earnings of comparable magnitude, which suggests some medium-run persistence in hourly wage gains from positive economic shocks. Table 4 also reports the cumulative effect for each outcome as the sum of coefficients over time. Compared to the main specification in Table 2 Panel D, the cumulative effects are smaller for any work and annual hours worked but moderately larger for hourly earnings and annual earnings.

Figure 2 explores impact timing via event-style 2SLS regression analysis. We define an oil and gas state of residence dummy equal to one for individuals living in the nine high oil and energy states and zero for the other 41 states and DC; we define a similar oil and gas state of birth dummy equal to one for individuals born in the nine high oil and gas states. We then interact each of these with year dummies to obtain two sets of year-specific treatment indicators. We define 2005 as the pre-event base year to which year-specific treatment effects are compared. 2SLS regressions are estimated for each of the four dependent variables by regressing the residence-state year-specific treatment indicators on the birth-state year-specific treatment indicators in first-stage regressions. The four graphs of Figure 2 present the second-stage year-specific treatment indicator coefficients and the 95% confidence intervals.[9] In interpreting Figure 2, it is helpful to recall Figure 1 showing that the percentage of oil and gas employment in high oil and gas states steadily increased after the early 2000s and peaked in 2014.

Figure 2(a) presents results for working during the year. The year-specific coefficients increase considerably after 2005 and peak in 2009 at more than three percentage points. The oil and gas boom initially increased overall employment rates, but the effect began fading over time well before oil and gas employment peaked in 2014. Figure 2(b) illustrates effects for log annual hours worked. Annual hours coefficients also rise quickly after 2005 and largely plateau above 0.04 during 2007-2014 before falling as oil and gas employment fell. Log hourly earnings coefficients in Figure 2(c) increase steadily from 2005-2013 and peak at 0.077 before falling

[9] Figure A1 presents OLS results using birth-state year-specific treatment indicators. As expected, results in Figure A1 follow the same pattern as Figure 2 but have smaller magnitudes because they do not account for out-migration and instead correspond to intent-to-treat effects similar to Panel B of Table 2.

after 2014. Log annual earnings coefficients in Figure 2(d) combine the effects on annual hours and hourly earnings, but the overall pattern is more similar to hourly earnings. Thus, the four outcomes differ somewhat in short and medium run effects consistent with Table 4. Wage responses are more enduring than employment responses.

3.4 Heterogeneous Impacts by Sex and Age

Table 5 presents 2SLS results by sex and age group to explore heterogeneous effects on employment and income. The oil and gas industry is heavily male, and complementary industries such as transportation and construction are also predominantly male, so we expect larger impacts on males than females. Additionally, we expect the impacts to be largest for younger workers. Older workers have often developed specific skills suited toward other industries and may be more reluctant to invest in new skills needed for the oil and gas industry. Similarly, oil and gas related jobs are often physically demanding with unpleasant work conditions that older workers may be less willing to accept. Furthermore, a strong state economy may especially benefit younger workers if it would otherwise take them considerable time after entering the labor market to find good jobs.

Panel A presents results for males ages 18-61, and Panel B presents results for females ages 18-61. As expected, the coefficient estimates are larger for males, but it is notable that women are also significantly positively affected. Men benefit more than women from oil and gas employment in their state, but women benefit too. Panels C, E, and G present results for males ages 18-29, 30-49, and 50-61, respectively. Panels D, F, and H present results for females ages 18-29, 30-49, and 50-61, respectively. For both men and women, the coefficient estimates are largest for younger workers. The coefficient estimates are also typically smallest for older workers. All of the coefficient estimates in Table 5 are statistically significant at the five percent level or higher except for three female regressions: Column 2 in Panel F and Columns 1 and 2 in Panel H. The age-sex groups all appear to benefit via higher hourly and annual earnings. Overall, younger males benefit the most, and older females benefit the least.

In appendix Table A3, we also estimate separate effects by sex for college graduates and non-college graduates, where we define college graduates as those having a four-year degree or higher education. Consistent with expectations, we find especially positive impacts on non-college graduates. We also find some positive effects on college graduates, including uniformly positive effects on hourly earnings and annual earnings. However, the potential for endogenous education decisions hinders our ability to draw strong conclusions for sub-samples based on education, so we relegate these to the appendix.

4. Conclusion

Recent developments in horizontal drilling and hydraulic fracturing powered a revolution in the U.S. oil and gas industry. Oil and gas employment more than doubled between 2000 and 2014 in several states. This study uses 2SLS to estimate causal effects of state oil and gas employment shares on individual employment and income. We instrument for the percent of employment in oil and gas in an individual's state of residence using the predicted percent of employment in oil and gas in their birth state.

We find positive and statistically significant effects of oil and gas employment in a state on employment and income. We also show that these effects do not just result from the direct effects of workers getting high-paying jobs in the oil and gas industry. Instead, there are large and important spillover effects to workers in other industries. A one percentage point increase in the oil and gas employment share in a state increases the average probability of employment by 1.4 percentage points and increases average annual earnings by 7.2 percent. Additionally, employment effects appear to weaken over time, while wage effects persist over time. We also document that effects are larger for men than they are for women and larger for younger than for older workers.

Fossil fuels contribute to global climate change and worsen local air quality, and these external costs rightly play an important role in public policy discussions about fossil fuel usage. However, policy discussions should also be aware that fossil fuels play a significant role in many state economies via royalty payments, firm profits, industry employee income, and multiplier effects increasing demand for other industries. Our study confirms that oil and gas development within a state has significantly positive labor market impacts.

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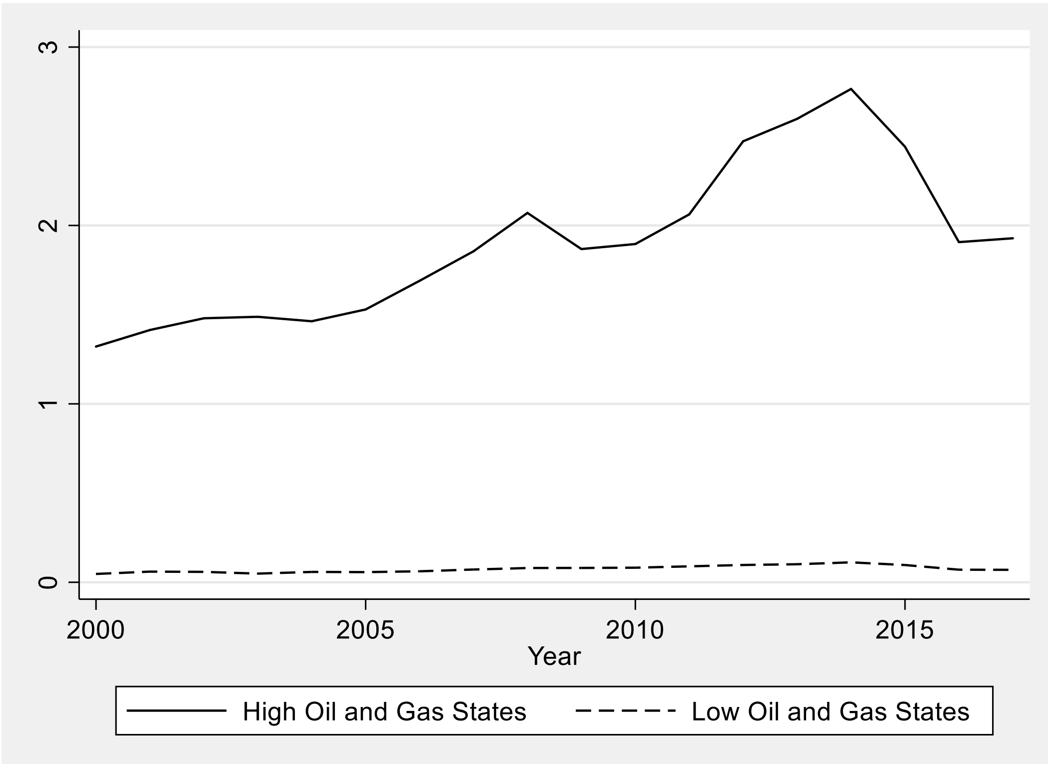
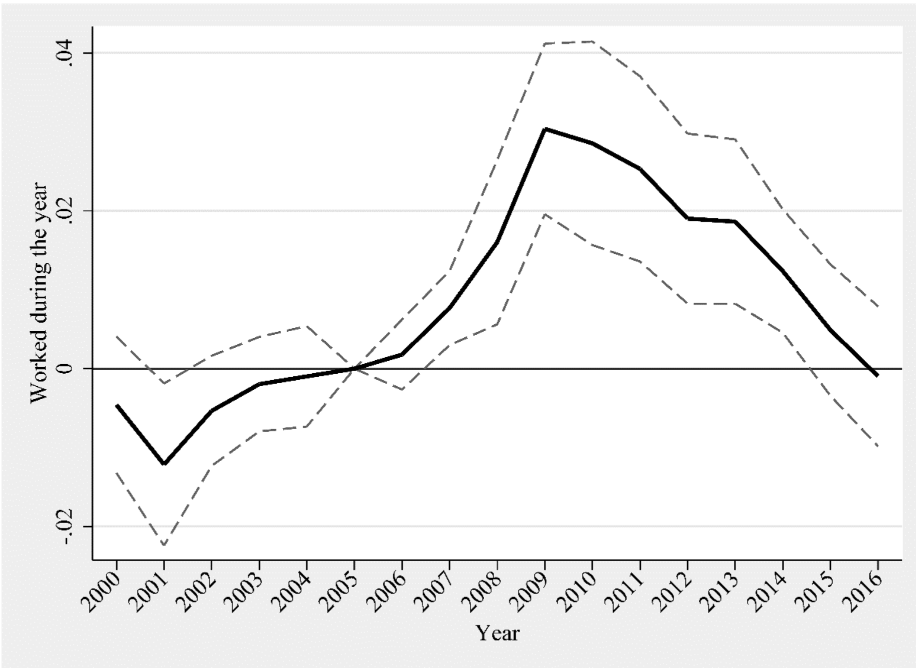
Figure 1: Percent of Employment in Oil and Gas in High and Low States, 2000-2016



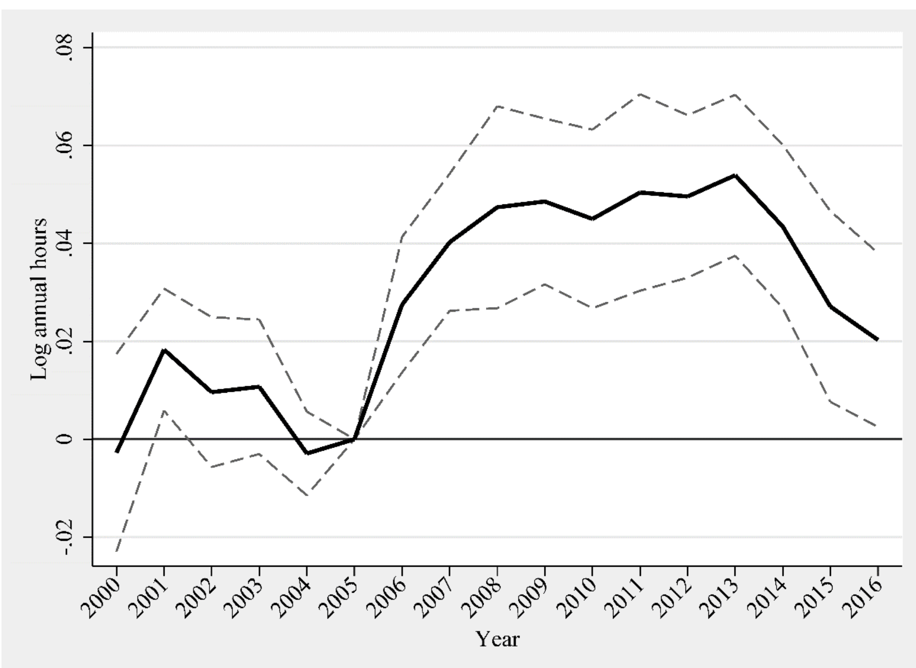
Notes: computed from IPUMS-USA data by the authors.

Figure 2: Event Study Analysis Using 2SLS Binary Treatments

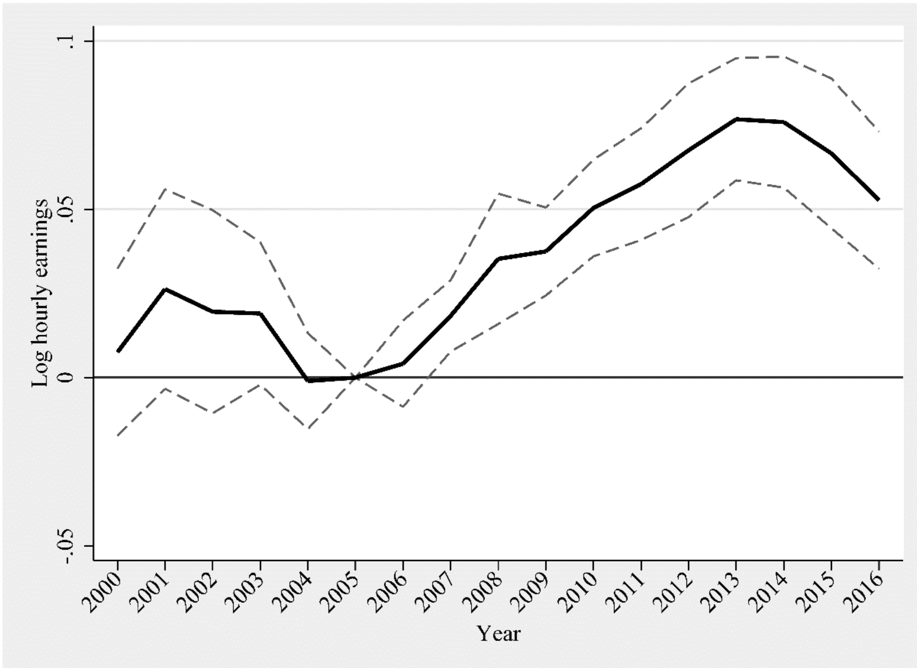
(a) Worked During Year



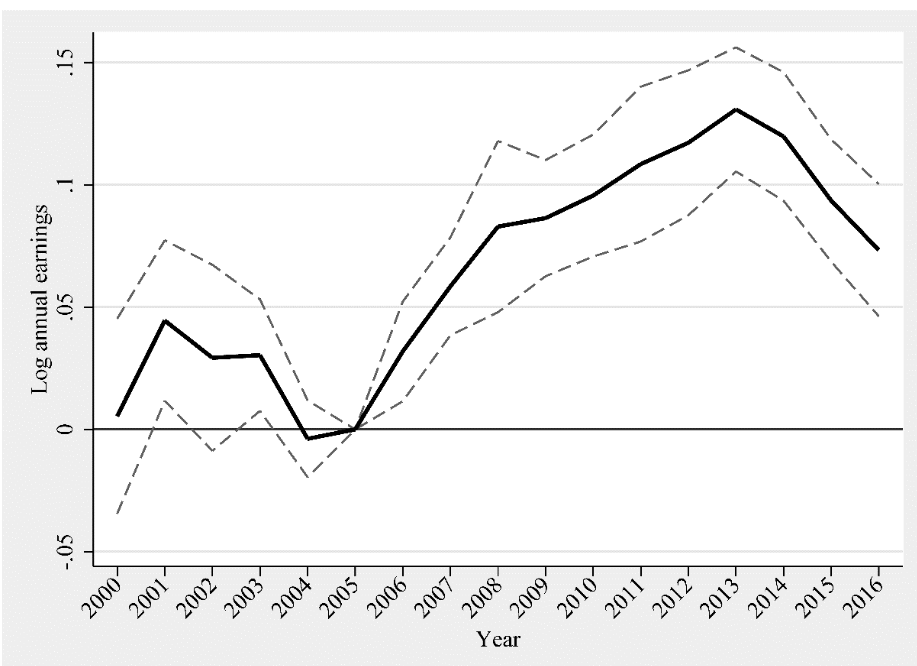
(b) Log Annual Hours



(c) Log Hourly Earnings



(d) Log Annual Earnings



Notes: The solid black lines indicate year-specific 2SLS regression coefficients for interactions between year dummies and a high oil and gas state dummy. The first stage regresses state of residence interaction terms on state of birth interaction terms. The dashed lines indicate the 95% confidence intervals. See text for further details.

Table 1: Sample Means for Main Variables

	(1) Full Sample	(2) 9 High Oil and Gas States	(3) 41 Other States and DC
Worked During Year	0.818	0.806	0.820
Annual Hours Worked	1856	1875	1854
Real Hourly Earnings ($2017)	25.99	23.80	26.33
Real Annual Earnings ($2017)	48,419	44,382	49,044
Percent of Employment in Oil and Gas in Residence State	0.342	1.509	0.158
Percent of Employment in Oil and Gas in Birth State	0.335	1.971	0.078
Predicted Percent of Employment in Oil and Gas in Birth State	0.350	2.084	0.077

Notes: The full sample includes 20,620,136 individuals in the 2001-2017 ACS ages 18-61, born in the U.S., residing in the U.S., and not in group quarters. Sample means for hours worked, hourly earnings, and annual earnings are restricted to observations with positive values for the respective variables. Sub-samples in Columns 2 and 3 are split based on state of birth. The 9 high oil and gas states are Alaska, Colorado, Louisiana, New Mexico, North Dakota, Oklahoma, Texas, West Virginia, and Wyoming.

Table 2: Estimated Effects of Oil and Gas Employment Shares on Employment and Income

Dependent Variable:	(1) Worked During Year	(2) Log Annual Hours	(3) Log Hourly Earnings	(4) Log Annual Earnings
A. OLS Using Residence-State Measure				
Percent of Employment in Oil and Gas	0.011	0.021	0.037	0.057
	(0.003)***	(0.004)***	(0.006)***	(0.008)***
B. OLS Using Birth-State Measure				
Percent of Employment in Oil and Gas	0.009	0.015	0.030	0.046
	(0.002)***	(0.004)***	(0.004)***	(0.006)***
C. OLS for Birth-State Residents				
Percent of Employment in Oil and Gas	0.012	0.025	0.047	0.071
	(0.003)***	(0.006)***	(0.007)***	(0.009)***
D. 2SLS Using Predicted Employment IV				
Percent of Employment in Oil and Gas	0.014	0.024	0.048	0.072
	(0.003)***	(0.005)***	(0.007)***	(0.009)***
First-Stage F-Statistic	175.32	183.34	183.44	183.44
Individual Observations	20,620,136	16,873,438	16,848,200	16,848,200

Notes: The percent of employment in oil and gas is the oil and gas employment in the state divided by total employment in the state (and then multiplied by 100) in year t-1. This is measured using state of residence in Panel A and state of birth in Panels B and C. Panel D instruments for the oil and gas percent in the state of residence using the predicted percent in an individual's state of birth. Panel A regressions include residence state fixed effects, region-year effects, and detailed controls for sex, age, and race/ethnicity. Panels B-D include birth state fixed effects, birth-region-year effects, and detailed controls for sex, age, and race/ethnicity. See the text for more details. Standard errors in parentheses are clustered by state of residence in Panel A and state of birth in Panels B-D. The first-stage F-Statistics in Panel D cluster by birth-state. ***Significantly different from zero at the one percent level.

Table 3: Main Sensitivity Analysis for IV Specification

Dependent Variable:	(1) Worked During Year	(2) Log Annual Hours	(3) Log Hourly Earnings	(4) Log Annual Earnings
A. Excluding Energy Industry Workers				
Percent of Employment in Oil and Gas	0.013	0.022	0.044	0.066
	(0.003)***	(0.005)***	(0.008)***	(0.009)***
B. Excluding 6 Consistently High Energy States				
Percent of Employment in Oil and Gas	0.013	0.022	0.067	0.089
	(0.005)***	(0.008)**	(0.005)***	(0.010)***
C. Excluding 9 High Energy States				
Percent of Employment in Oil and Gas	0.016	0.052	0.064	0.116
	(0.009)*	(0.020)**	(0.025)**	(0.035)***
D. Excluding ACS Years 2008-2012				
Percent of Employment in Oil and Gas	0.014	0.024	0.050	0.073
	(0.003)***	(0.006)***	(0.008)***	(0.009)***
E. Controlling for Oil and Gas Non-Labor GDP				
Percent of Employment in Oil and Gas	0.010	0.020	0.053	0.073
	(0.003)***	(0.006)***	(0.007)***	(0.009)***
F. Adding Shift-Share Control Variable				
Percent of Employment in Oil and Gas	0.013	0.024	0.044	0.068
	(0.004)***	(0.006)***	(0.007)***	(0.010)***
G. Controlling for Education, Marriage, and Children				
Percent of Employment in Oil and Gas	0.016	0.026	0.055	0.081
	(0.003)***	(0.005)***	(0.006)***	(0.009)***
H. Birth and Residence-based Fixed Effects				
Percent of Employment in Oil and Gas	0.014	0.024	0.051	0.075
	(0.003)***	(0.005)***	(0.008)***	(0.009)***

Notes: Standard errors in parentheses are clustered by state of birth. First-Stage F-Statistics are similar to Table 2 and are suppressed to conserve space. *Significantly different from zero at the ten percent level; **Significant at the five percent level; ***Significant at the one percent level.

Table 4: IV Estimates for Effects over Time

Dependent Variable:	(1) Worked During Year	(2) Log Annual Hours	(3) Log Hourly Earnings	(4) Log Annual Earnings
Percent of Employment in Oil and Gas in t	0.011	0.029	0.034	0.063
	(0.003)***	(0.004)***	(0.005)***	(0.007)***
Percent of Employment in Oil and Gas in t-1	-0.001	0.001	0.006	0.007
	(0.002)	(0.003)	(0.007)	(0.007)
Percent of Employment in Oil and Gas in t-2	-0.001	-0.014	0.005	-0.010
	(0.003)	(0.004)***	(0.006)	(0.008)
Percent of Employment in Oil and Gas in t-3	-0.005	-0.005	0.004	-0.001
	(0.002)*	(0.008)	(0.006)	(0.009)
Percent of Employment in Oil and Gas in t-4	0.0001	0.003	0.018	0.020
	(0.003)	(0.007)	(0.006)***	(0.011)*
Cumulative Effect	0.004	0.014	0.067	0.079
Joint P-value	<0.0001	<0.0001	<0.0001	<0.0001
First-Stage Joint F-Statistic	32.15	34.32	34.24	34.24

Notes: Standard errors in parentheses and first-stage joint F-Statistics are clustered by state of birth. We jointly instrument for the percent of employment in oil and gas for all five time periods using corresponding time-lag variables for the predicted percent of employment in oil and gas in an individual's birth state. The Cumulative Effect is the sum of coefficients over time. The Joint P-value is from an F-statistic test that the coefficients are jointly zero. *Significantly different from zero at the ten percent level; ***Significant at the one percent level.

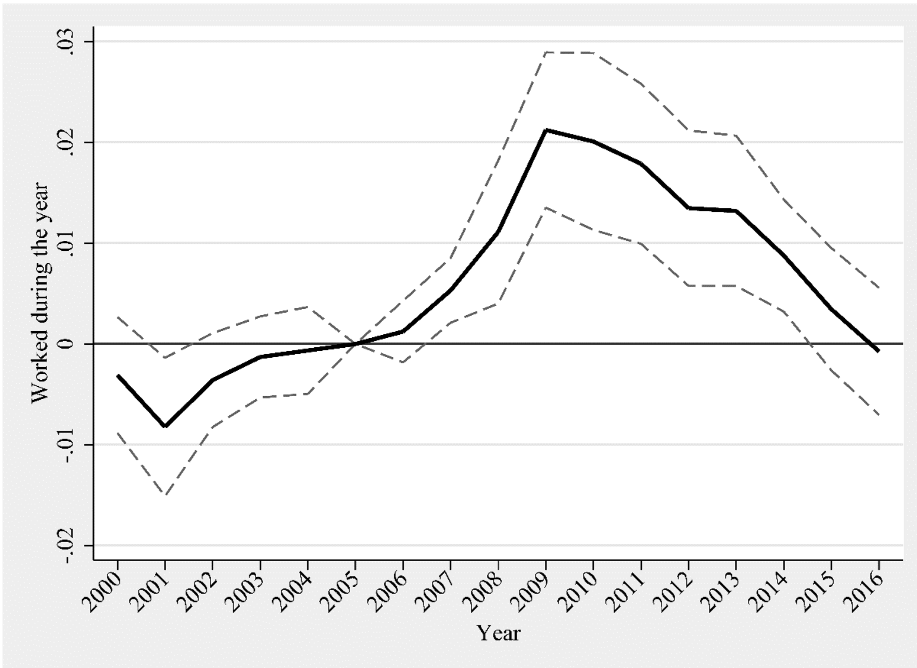
Table 5: IV Estimates by Sex and Age Group

Dependent Variable:	(1) Worked During Year	(2) Log Annual Hours	(3) Log Hourly Earnings	(4) Log Annual Earnings
A. Males Ages 18-61				
Percent of Employment in Oil and Gas	0.016	0.034	0.060	0.094
	(0.003)***	(0.007)***	(0.008)***	(0.011)***
B. Females Ages 18-61				
Percent of Employment in Oil and Gas	0.012	0.014	0.035	0.049
	(0.003)***	(0.004)***	(0.008)***	(0.008)***
C. Males Ages 18-29				
Percent of Employment in Oil and Gas	0.021	0.059	0.069	0.127
	(0.005)***	(0.009)***	(0.010)***	(0.015)***
D. Females Ages 18-29				
Percent of Employment in Oil and Gas	0.019	0.031	0.041	0.071
	(0.005)***	(0.013)**	(0.005)***	(0.012)***
E. Males Ages 30-49				
Percent of Employment in Oil and Gas	0.015	0.030	0.063	0.093
	(0.002)***	(0.007)***	(0.008)***	(0.011)***
F. Females Ages 30-49				
Percent of Employment in Oil and Gas	0.012	0.006	0.036	0.042
	(0.003)***	(0.004)	(0.010)***	(0.011)***
G. Males Ages 50-61				
Percent of Employment in Oil and Gas	0.011	0.013	0.046	0.059
	(0.004)***	(0.005)**	(0.010)***	(0.011)***
H. Females Ages 50-61				
Percent of Employment in Oil and Gas	0.007	0.009	0.031	0.040
	(0.004)*	(0.007)	(0.008)***	(0.013)***

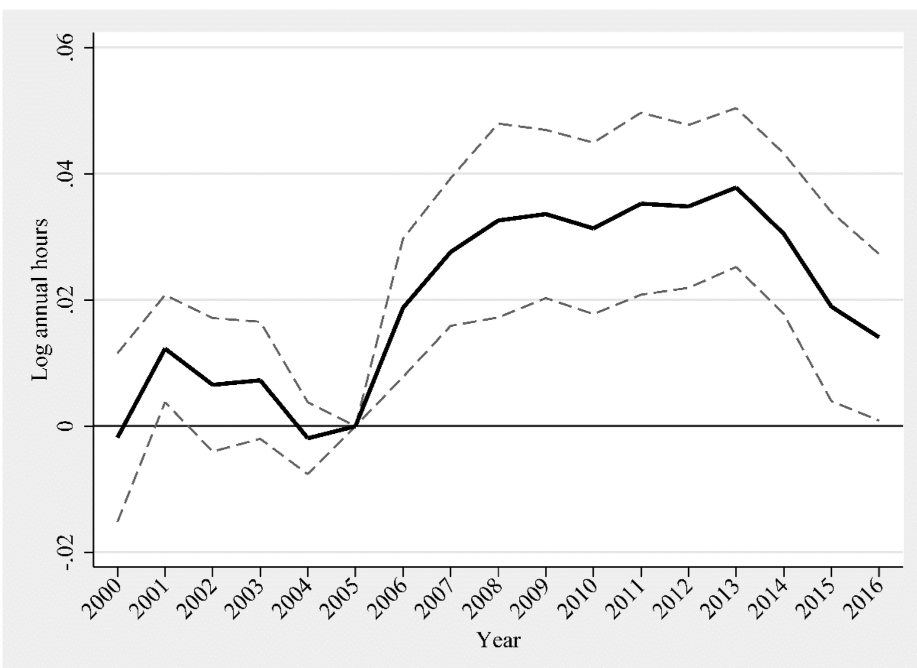
Notes: Standard errors in parentheses are clustered by state of birth. First-Stage F-Statistics are similar to Table 2 and are suppressed to conserve space. *Significantly different from zero at the ten percent level; **Significant at the five percent level; ***Significant at the one percent level.

Figure A1: Event Study Analysis using OLS for Birth-State Binary Treatments

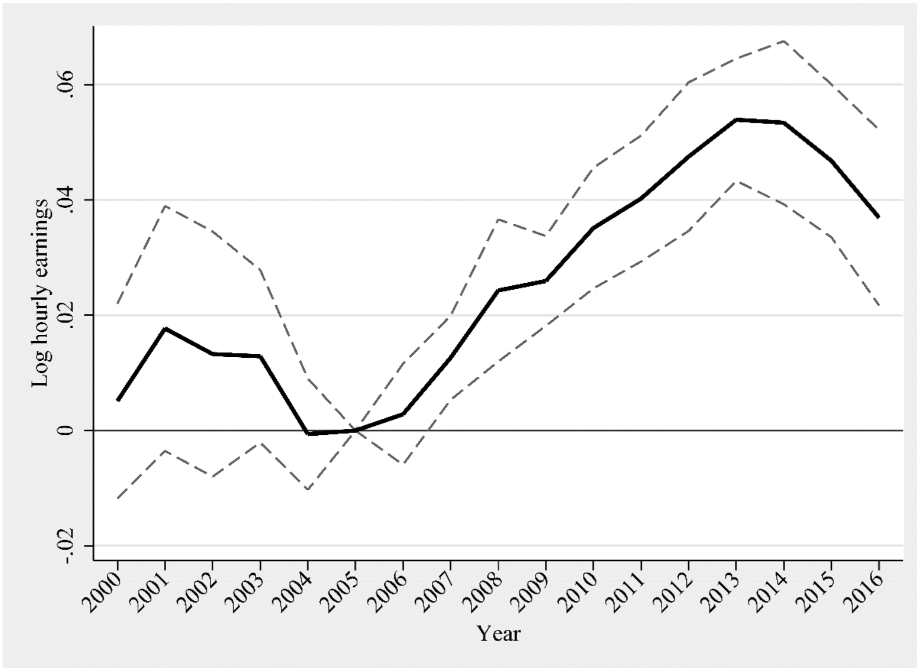
(a) Worked During Year



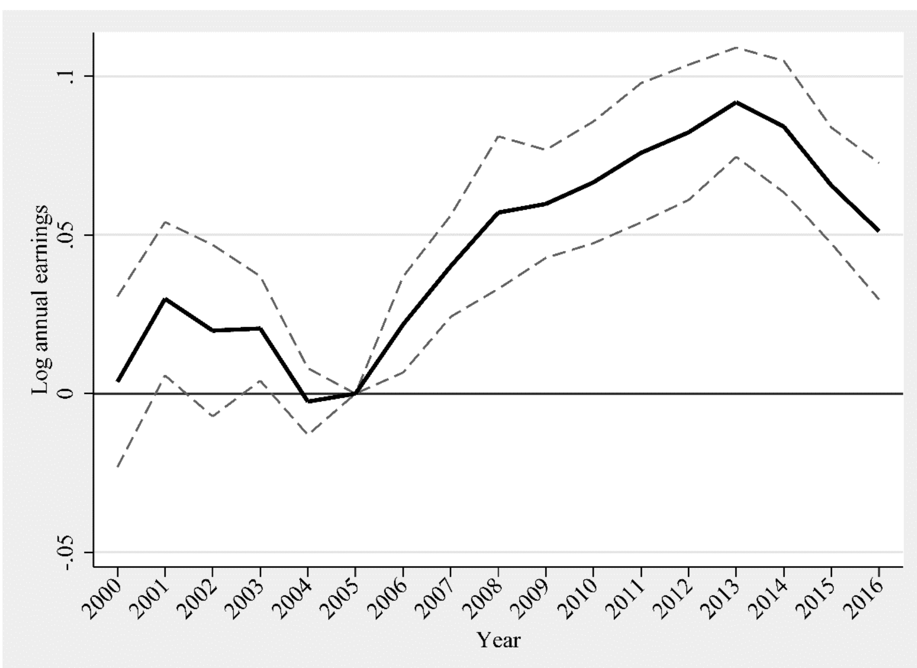
(b) Log Annual Hours



(c) Log Hourly Earnings



(d) Log Annual Earnings



Notes: The solid black lines indicate regression coefficients for binary treatment variables constructed as interactions between year dummies and a dummy for being born in a high oil and gas state. The dashed lines indicate the 95% confidence intervals. See text for further details.

Table A1: IV Estimates for Alternative Outcomes

Dependent Variable:	(1) Worked During Week	(2) Log Weekly Hours	(3) Log Earnings with Hours Controls	(4) Log Mean Annual Earnings
Percent of Employment in Oil and Gas	0.013	0.014	0.045	0.083
	(0.003)***	(0.003)***	(0.007)***	(0.012)***

Notes: Standard errors in parentheses are clustered by state of birth. First-Stage F-Statistics are similar to Table 2 and are suppressed to conserve space. The dependent variables are similar to the main counterparts. See the text for more details. ***Significantly different from zero at the one percent level.

Table A2: Additional Sensitivity Analysis

Dependent Variable:	(1) Worked During Year	(2) Log Annual Hours	(3) Log Hourly Earnings	(4) Log Annual Earnings
A. OLS for Birth-State Out-Migrants using Residence-Based Measures				
Percent of Employment in Oil and Gas	0.008	0.014	0.022	0.036
	(0.003)***	(0.003)***	(0.006)***	(0.008)***
B. 2SLS Using Actual Birth-State Percent Employment in Oil and Gas for IV				
Percent of Employment in Oil and Gas	0.013	0.024	0.048	0.072
	(0.003)***	(0.005)***	(0.008)***	(0.010)***
C. 2SLS with State-Specific Linear Time Trends				
Percent of Employment in Oil and Gas	0.008	0.023	0.029	0.052
	(0.005)*	(0.007)***	(0.007)***	(0.012)***

Notes: Standard errors in parentheses are clustered by state of residence in Panel A and state of birth in Panels B and C. First-stage F-Statistics in Panels B and C are similar to Table 2 and are suppressed to conserve space. *Significantly different from zero at the ten percent level; ***Significant at the one percent level.

Table A3: IV Estimates by Sex and Education

Dependent Variable:	(1) Worked During Year	(2) Log Annual Hours	(3) Log Hourly Earnings	(4) Log Annual Earnings
A. Male Non-College Graduates				
Percent of Employment in Oil and Gas	0.020	0.039	0.065	0.104
	(0.004)***	(0.007)***	(0.008)***	(0.012)***
B. Male College Graduates				
Percent of Employment in Oil and Gas	0.003	0.024	0.060	0.084
	(0.002)	(0.005)***	(0.007)***	(0.008)***
C. Female Non-College Graduates				
Percent of Employment in Oil and Gas	0.019	0.019	0.041	0.060
	(0.003)***	(0.006)***	(0.008)***	(0.009)***
D. Female College Graduates				
Percent of Employment in Oil and Gas	-0.003	0.002	0.035	0.038
	(0.002)	(0.003)	(0.007)***	(0.008)***

Notes: Standard errors in parentheses are clustered by state of birth. First-Stage F-Statistics are similar to Table 2 and are suppressed to conserve space. ***Significantly different from zero at the one percent level.