The shale revolution and entrepreneurship: an assessment of the relationship between energy sector expansion and small business entrepreneurship in US counties

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Abstract

A vast literature documents an important role that entrepreneurs play in regional economic growth and overall regional socioeconomic wellbeing. Entrepreneurship is particularly important for economic health of rural and remote areas. The recent shale boom brought growth to many communities creating new jobs; however, it is unclear how these effects are distributed across self-employed and wage and salary segments of local economies. The resource curse literature suggests that a booming energy sector may crowd out entrepreneurship. Given the self-reinforcing nature of local self-employment and entrepreneurship in general, such a negative impact of expanding energy sector, if present, is likely to suppress future growth prospects in regions that experience the shale revolution.

Using SUR and IV approaches and a differencing strategy, this paper estimates the effects of the growth in oil and gas extraction industry on self-employment growth in metropolitan and rural US counties during the 2001-2013 period. The results suggest that after three years, oil and gas sector expansion tends to crowd out self-employment. In contrast, energy sector expansion promotes wage and salary employment growth in nonmetro counties but has crowding out effects in metro counties. Overall, we find that the expanding energy sector suppresses self-employment, especially in rural communities, in line with one mechanism of the resource curse.

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Introduction

A long-standing and prominent research tradition highlights the importance of entrepreneurship for economic performance of nations and regions (see Carree & Thurik (2010) and Praag & Versloot (2007) for detailed reviews). Self-employment, as one example of risk-taking and entrepreneurship, fosters employment and income growth, at least during certain time periods (Carree, Congregado, Golpe, & van Stel, 2015; Goetz, Fleming, & Rupasingha, 2012; Rupasingha & Goetz, 2013; Stephens & Partridge, 2011). In US counties, the employment growth multipliers from self-employment are found to be considerably larger than corresponding multipliers from increases in wage and salary employment (Tsvetkova, Partridge, & Betz, forthcoming). The evidence also suggests that self-employment plays a key role in promoting wellbeing of rural communities that may lack the advantages of agglomeration or other engines of growth (Stephens, Partridge, & Faggian, 2013).

For these reasons, understanding the drivers of self-employment is crucial for informed scholarly and policy debate. In this study, we ask the following question: what are the effects of a potentially disruptive (positive or negative) shock on self-employment in urban and rural US counties, particularly focusing on what is happening in energy boomtowns and asking whether their growth might be unsustainable? More specifically, we study how the recent boom in the US energy sector due to the "shale revolution" affects self-employment. The importance of this research comes from the crucial role of entrepreneurship in economic development and the need to better understand the consequences of the shale revolution and boomtowns in general—i.e., do booms lay the seeds of decline in the affected regions by crowding out future entrepreneurship?

At the international level, research has highlighted the possibility of both a resource curse and a resource blessing with empirical evidence primarily pointing to the negative relationship between resource-dependence and economic growth, which is observable mostly in less developed countries (Gylfason, Herbertsson, & Zoega, 1999; Sachs & Warner, 2001; Sala-I-Martin, Doppelhofer, & Miller, 2004). Theoretically, both these outcomes can co-exist with efficient allocation of production resources and sufficient human capital being the necessary conditions for avoiding the resource curse phenomenon (Shao & Yang, 2014). It has been noted, mostly within the context of developing and transition countries, that resource abundance can shift economic resources from efficient entrepreneurship toward rent seeking (Kronenberg, 2004; Majbouri, 2016; Torvik, 2002; Van der Ploeg, 2011). In mature economies, however, it is hoped that institutions guard against such a possibility. Even if opportunities for rent-seeking in the US are minor and are not amplified by the recent shale revolution, there are several other mechanisms for an expanding energy sector to suppress entrepreneurship and self-employment in particular.

Firstly, it may be prohibitively costly for self-employed to start and/or continue operations when oil and gas extraction bids wages and rents up, as suggested by the Dutch disease hypothesis (Corden, 1984; Van Wijnbergen, 1984). Secondly, potential self-employed workers may prefer to accept paid jobs in the expanding energy sector, or in other sectors that serve the energy industry and its workers. In line with this argument, a strand of literature that focuses on resources such as coal shows that the legacy of natural resource development persistently dampens entrepreneurship and lowers long-term growth in the US regions (Betz, Farren, Lobao, & Partridge, 2015; Chinitz, 1972; Glaeser, Kerr, & Kerr, 2015). The mechanism of this negative relationship may be both intertemporal and intratemporal, as discussed, for example in Chinitz (1972) and Glaeser et al. (2015), but the design of previous studies allows for systematic investigation of the intertemporal effect only. Our models are built to distinguish the contemporaneous and legacy effects of energy, as well as the impacts of location above mostly gas or mostly oil shale plays.

On the other hand, an oil and gas boom may lead to improved medium- and long-term economic performance especially within regions of a mature market economy. In the US, for example, the shale revolution is reducing country's dependence on foreign oil and has the potential to diversify economy (Brown & Yucel, 2013). Some commentators have discussed the potential of the energy sector to "jump-start" the economy lifting its long-term growth (Nyquist & Lund, 2014). Theoretically this would be possible if the recent expansion of the shale oil and gas industry serves as a 'big push' that takes resource-rich rural and urban communities to a new growth trajectory through the locally accumulated wealth helping to enhance the agglomeration effects (Sachs & Warner, 1999). To somewhat rephrase the big push literature (Murphy & Shleifer, 1989; Rosenstein-Rodan, 1943), development of unconventional energy resources has potential to sufficiently expand local demand so that entrepreneurs would have an incentive to strengthen and diversify local economies, taking them to a level of self-reinforcing growth.

Contradictory theoretical and empirical perspectives on the effects of natural resources call for further investigations with specific focus on the distribution of gains from natural resource booms within regional economies of a mature market economy. Yet, there are few studies that specifically examine the relationship between the natural resource dependence of a US region on the one hand and entrepreneurship or self-employment on the other (Betz et al., 2015; Glaeser et al., 2015). Those few studies focus on coal mining, which has a different history and industry evolution than other resource sectors, especially the oil and gas industry, which has underwent a rapid expansion with the development of unconventional shale drilling techniques. To the best of our knowledge, our study is the first to explicitly address the question of the contemporaneous relationship between expansion in the oil and gas sector and entrepreneurship in both rural and urban settings.

Another advantage of our study, compared to most of related research in the US context, is the use of a measure of self-employment based on the American Community Survey (ACS), which counts as self-employed only those who consider self-employment as their *primary* source of income. This ensures that we do not overestimate the number of self-employed people, as is inevitably the case if US Internal Revenue Service (IRS) or US Bureau of Economic Analysis (BEA) data are used. For example, a college professor who gives a keynote for an honorarium would be counted as a wage and salary worker *and* as a self-employed worker for receiving self-employment income in both the IRS and the BEA data. Clearly policy discussion revolving around entrepreneurship and small business expansion is not focused on such causal forms of self-employment.

Existing research documents job-creating effects of the recent expansion in oil and gas industry in the US (Lee, 2015; Tsvetkova & Partridge, 2016; Weber, 2012; Weinstein, 2014). To assess the distribution of these gains between self-employed and paid segments of the local economies, we separately estimate the effects of energy sector on self-employed (SE) and wage and salary (WS) job creation in nonmetro and metro counties after accounting for legacy effects. Finally, we compare self-employment generating effects of the (positive) shock in the energy sector to shocks in the rest of the economy. This allows us placing our findings in a broader perspective of self-employment economic determinants and their relative importance.

Estimation results suggest that after three years, energy sector expansion tends to crowd out SE in nonmetropolitan counties with disproportionately more self-employment jobs being lost in counties that experience greater growth in oil and gas employment. In contrast, a location above a major oil play is positively related to SE, whereas legacy effects are not detected. In the case of wage and salary employment, the picture is different. Energy sector expansion promotes WS employment in nonmetro counties but has crowding out effects in the metro sample. Noteworthy in the analysis of paid employment, the legacy effects are present in both metro and nonmetro counties with mining employment in 1985 having a persistent positive effect on WS employment decades later. Another important finding of this research is that the positive economic shocks in the rest of the economy have job-creating effects in all models and subsamples when compared to the equal-sized shocks in the energy sector. This suggests that a narrow energy-based development strategy is likely to produce inferior results compared to a broad and industrially balanced approach.

The rest of the paper is organized as follows. The next section positions our research within several strands of existing inquiry. It briefly introduces the literature that demonstrates the benefits of SE for local economic development, describes the resource curse hypothesis and summarizes empirical evidence on the relationship between recent energy boom and various economic outcomes for US regions. Section three describes our estimation approach and data with sections four and five presenting estimation results and sensitivity checks respectively. The last section offers concluding remarks and suggests avenues for further research.

Self-employment, resource endowment and economic performance

The importance of entrepreneurship as an engine of regional economic growth is widely recognized (Malecki, 1994; Santarelli & Vivarelli, 2007; Stephens et al., 2013; Tsvetkova, 2015). Although entrepreneurship is often measured by the share of self-employment in empirical studies (e.g. see Acs, Autio, and Szerb (2014) for an explanation why SE rate or self-employment entry might be a superior measure of entrepreneurship compared to start-up rates), self-employment in itself has not received comparable attention, perhaps due to general expectations of the low impact of the self-employed on local economic performance (Goetz et al., 2012). The situation has changed recently. For one, while not universal, a large share of small business start-ups is self-employed and when success is more apparent, these businesses tend to incorporate. In the realm of academic and policy debates, scholars and policymakers seek to identify alternative/additional growth determinants as regional and national economies struggled through the recession. As a result of this interest, growing empirical evidence points to the positive role of SE in income and job growth (Carree et al., 2015; Goetz et al., 2012; Rupasingha & Goetz, 2013) and explains why SE may be one of very few (or sometimes even the only) mechanism of growth promotion in remote and lagging communities (Stephens & Partridge, 2011; Stephens et al., 2013).

The apparent and sizeable impact of SE on the economic fortunes of localities calls for a more careful examination of its determinants and whether boomtowns' characteristics support the existence of the self-employed sector. Current research finds positive feedback effects from past levels of entrepreneurship (Andersson, 2015; Glaeser et al., 2015; Stephens & Partridge, 2011; Stephens et al., 2013). In this light, anything that promotes "entrepreneurial culture" is likely to have lasting positive effects due to the self-perpetuating nature of the self-employment phenomenon. By the same token, external forces that erode the SE or entrepreneurial base of a locality may plant the seeds of persistent economic underperformance.

The explosive recent growth in the energy sector may be one such factor that, theoretically, has offsetting positive and negative effects on small businesses and SE in particular. If the expansion of the unconventional oil and gas extraction is able to sufficiently expand local demand base for the favorable effects to be felt by the SE in line with the "big push" hypotheses (Murphy & Shleifer, 1989; Rosenstein-Rodan, 1943), one should welcome energy developments due to their both direct and indirect (input-output effects and via stimulating local self-employment) positive economic impacts. Alternatively, one or more mechanisms of the resource curse (for example,the Dutch

Decease or a simple reorientation of economic agents to rent-seeking instead of entrepreneurship) may be at work. As a result, the negative impacts on entrepreneurship may potentially more than offset all positive consequences of oil and gas industry growth, especially in the long run and/or in the bust stage of the energy cycle.

The empirical investigations of the relationship between energy sector growth in the US counties and total employment effects find positive, but rather modest and varying across space, impacts (Brown, 2014; Munasib & Rickman, 2015; Tsvetkova & Partridge, 2016; Weber, 2012, 2014; Weinstein, 2014). These studies stop short of shedding light on the distribution of the effects across proprietors and WS segments of local economies. Yet, a positive *aggregate* effect may still conceal crowding out in some sectors. If this is the case for SE, resource-rich counties that rely heavily on energy industry may be planting the seeds of their future stagnation and even decline if the negative consequences of meager entrepreneurship are felt after the boom stage of the energy cycle passes.

With respect to natural resource endowment and its effects on economic performance, it is still an empirical question if natural resources are a curse or a blessing. An expansive literature, mostly at the national level, suggests a negative relationship between natural resource endowment and economic growth, the so-called natural resource curse (Gylfason, Herbertsson, & Zoega, 1999; Sachs & Warner, 2001; Sala-I-Martin, Doppelhofer, & Miller, 2004).[1] Several explanations have been offered for this pattern. The so-called Dutch Disease (Sala-i-Martin & Subramanian, 2013), corruption and ill-functioning institutions (Bhattacharyya & Hodler, 2010; Bjorvatn, Farzanegan, & Schneider, 2012; Sala-i-Martin & Subramanian, 2013); concentration of production and export in the resource sector that hampers diversification (Murshed & Serino, 2011); a lack of incentives for human capital accumulation (Black, McKinnish, & Sanders, 2005; Blanco & Grier, 2012; Gylfason, 2001; Rickman, Wang & Winters, 2017) and crowding out entrepreneurship and innovation (Betz et al., 2015; Gylfason, 2000; Sachs & Warner, 1999) are hypothesized to play a role. Some authors, however, argue that market

[1] For an alternative view see Alexeev and Conrad (2009) and Cavalcanti, Mohaddes, and Raissi (2011).

imperfections unrelated to resources explain slower growth of natural resource abundant economies (Gylfason & Zoega, 2014; Manzano & Rigobon, 2001).

At the subnational US level research provides conflicting results regarding the resource curse hypothesis. On the one hand, state-level analysis seems to reveal a negative effect of the primary-sector share on various indicators of economic performance, although the exact mechanism of this relationship may work through factors other than the resource endowment *per se* (Boyce & Herbert Emery, 2011; Freeman, 2009; James & James, 2011; Kilkenny & Partridge, 2009; Papyrakis & Gerlagh, 2007). On the other, county-level investigations mostly find that natural resources boost economic performance, at least during the booms, potentially suggesting that big-push effects could prevail (Brown, 2014; Paredes, Komarek, & Loveridge, 2015; Weber, 2012, 2014; Weinstein, 2014).

Studies that look specifically at the relationship between resource dependence and entrepreneurship or SE are rare. Perhaps the first investigation that spelled out the mechanism of the negative effect of mining on entrepreneurship is Chinitz (1972). In the comparison of industrial structures of New York and Pittsburg, he suggests that the presence of ore mines close to the latter city led to its specialization in steel with considerable economies of scale and, hence, large enterprises. Such specialization is hypothesized to be detrimental to entrepreneurship. An economy dominated by large-scale production crowds out entrepreneurs both contemporary (potential entrepreneurs get employed by large companies or have difficulties to access necessary resources) and over time (the areas close to natural resources are likely to lack entrepreneurial skills and favorable attitudes to entrepreneurship that are passed on to the next generations). Glaeser et al. (2015) follow Chinitz's intuition and use historic data on mines to instrument for entrepreneurship in an assessment of the entrepreneurship effects on urban growth. The authors find that proximity to historic mines in year 1900 is positively related to an average size of establishments[2] across urban economies decades later. In a similar vein, Betz et al. (2015) use instrumental variable (IV) approach to estimate the

[2] Regional economies that predominantly consist of smaller establishments naturally have higher ratio of business heads (many of whom may be entrepreneurs) to paid employees (Glaeser et al., 2015) and tend to grow faster (Glaeser, Kallal & Scheinkman, 1992; Glaeser, Kerr & Ponzetto, 2010).

effects of coal mining intensity on entrepreneurship. They conclude that the share of coal mining employment has a negative effect on the proprietors' share of total employment. This effect is greater during the period of higher coal prices with counties in the lagging Appalachian region of the US experiencing even more crowding out of entrepreneurship.

Empirical model and data

Although the evidence on the relationship between resource-dependence and entrepreneurship is scarce, it suggests that the legacy of natural resource development has a persistent dampening effect. Several empirical studies that specifically study the impact of resources on entrepreneurship describe both intertemporal and contemporaneous mechanisms of this relationship. Their research design, however, allows for systematic investigation of the intertemporal effects only. In contrast, we are interested in the contemporaneous impact of oil and gas development on entrepreneurship in rural and urban communities. To separate the intertemporal and contemporaneous effects, we employ a unique modeling approach. Our models rely on differencing strategy and include an explicit control for the legacy of mining (besides other control variables) and dummy variables to account for persistent disequilibrium effects of historic energy sector agglomerations and of location above mostly oil and/or mostly gas plays. The first differencing allows to remove location-specific invariant characteristics (county fixed effects), such as history, culture, climate, and business climate[3], The models are estimated using the Seemingly Unrelated Regression (SUR) approach where equations as (1) below are simultaneously estimated for total employment, employment in traded and nontraded industries (reported in the estimation results section), and in eleven individual sectors[4] (not reported) in order to improve the efficiency of our estimates[5]. The sensitivity analysis part of the paper employs instrumental variable approach that should mitigate

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[3] Some researchers argue that characteristics of place are important for rural entrepreneurship (Stathopoulou, Psaltopoulos, & Skuras, 2004).

[4] These sectors are: agriculture; manufacturing; construction; transportation and warehousing; retail trade; wholesale trade; accommodation and food services; real estate, finance and insurance; information services; professional, scientific and technical services.

[5] Compared to the OLS estimation results, fewer variables attain statistical significance. Besides, our estimates of the spill-over effects from the oil and gas sector are mostly smaller than the ones reported by previous studies (Tsvetkova & Partridge, 2016; Weinstein, 2014). We, therefore, feel confident reporting the SUR results as conservative estimates.

any concerns related to any potential endogeneity if it is not accounted for in the base models. There are 3,028 (1,987 nonmetro and 1,041 metro) counties in our sample.

The empirical model estimated in this paper is given below (1):

$$\Delta Y_{ic} = \beta_0 + \beta_1 \Delta EnVar_c + \beta_2 \Delta EnVarSq_c + \beta_3 Dummies_c + \sum_{s=4}^{5} \beta_s \Delta IndMix_{ic}$$

$$+X\beta + \theta_t + \varepsilon_c \qquad (1)$$

where the type of employment (SE or WS) is denoted by *i*, *c* stands for a county and *t* for a time period. The dependent variable, $\Delta Y_{ic} = Y_{ict} - Y_{ict-3}$, is the first difference in county SE or WS employment three-year growth *calculated relative to the total county employment* in the beginning of a period[6]: $Y_{ict} = \frac{(Emp_{ict} - Emp_{ict-3})}{Emp_{ct-3}} * 100$.

Energy employment in this study is defined as combined employment in NAICS2111 (Oil and Gas Extraction) and NAICS2131 (Support Activities for Mining) industries. The change in energy employment growth, $\Delta EnVar_c$, is the main explanatory variable that captures the contemporaneous effect of energy sector expansion on employment growth in the SE and WS paid segments of a local economy. $\Delta EnVar_c$ is a differenced change in oil and gas employment growth calculated using *total* county employment as the base ($\Delta EnVar_c = EnVar_{ct} - EnVar_{ct-3}$ and $EnVar_{ct} = \frac{(EnEmp_{ct} - EnEmp_{ct-3})}{Emp_{ct-3}} * 100$).

Because both the dependent and the key employment explanatory variables are calculated relative to the *total county employment,* the coefficient β_1 is a multiplier that shows how many SE or WS jobs are added in a county per each new job in the energy sector. To account for potential nonlinearity, Equation (1) includes variable $\Delta EnVar_c$ in a squared form, $\Delta EnVarSq_c$. In order to separate the contemporaneous effects of recent developments in the oil and gas industry from the legacy effects that have persistent

[6] For example, if county's self-employment growth rate calculated with total county employment as the base was 0.5 percent between years 2004 and 2007 and the same measure was 0.1 percent between years 2001 and 2004, the value of the dependent variable for this specific county in year 2007 is 0.4 percent. There are three observations for each county in the data set, calculated in the same fashion as above and denoted by years 2007, 2010 and 2013.

effects on growth decades later, the models include three measures that account for the legacy of mining and the historic presence of oil and gas resource infrastructure and relevant supply chains. The key control variable that allows conditioning out the effects of any historical legacy of resource extraction in a community is the 1985 employment share in mining, *Mining85*, calculated as described in Partridge and Rickman (2006). *Mining85* captures historical agglomerations of the energy sector left behind by the 1970s-1980s energy boom with associated infrastructure and potentially favorable attitudes toward the energy industry that may be related to the expansion of the industry during the recent boom. Two dummy variables that indicate if a county sits on mostly oil (*Oil Dummy*) or mostly gas (*Gas Dummy*) plays[7] should capture the potential influence of these two types of resource endowment. *Mining85* and the dummies, together with first-differencing, should control for historic trends and fixed effects in entrepreneurship stemming from proximity to mines, so that the main estimated coefficients show the impact of the recent oil and gas boom only.

An industry mix employment growth measure, sometimes called the Bartik instrument, $IndMix_{ic}$, is an important control for labor demand shocks on local SE and WS employment. This measure is based on national economic trends and on the initial industry and SE versus WS compositions of a county, which makes it an exogenous demand shock as long as there is no lagged labor supply response that is not accounted for in the conditioning variables such as age or education, which is assumed to be not the case. Intuitively, the industry mix variable is the expected employment growth rate if all of the industries grow at their respective national growth rates.

Our industry mix term includes all industries *except* the oil and gas sector, which is captured by $\Delta EnVar$. The β_s coefficient reflects the multiplier effects of the average SE and WS demand shocks in all *other* industries in a county on total proprietors and paid employment growth. Inclusion of this variable along with the energy employment terms allows for comparison of the spillover employment impacts from changes in oil and gas relative to equal-sized shocks across the remainder of the local economy.

Equation (2) shows how the industry mix for SE, SE_IndMix_c, is calculated. The

[7] Mostly oil plays: Bakken, Eagle Ford, Permian; mostly gas plays: Marcellus, Haynesville, Niobrara. We use the geospatial map of shale oil and tight gas plays from the US Energy Information Administration and geospatial analysis software to determine which counties sit over these oil and gas plays.

industry mix measure for WS employment is calculated identically.

$$SE\_IndMix_c = \sum_n SE\_S_{cnt-3} SE\_NG_{cnt-3,t} \qquad (2)$$

where SE_S_{cnt-3} is self-employment share of industry *n* (*n* ≠ NAICS2111 or NAICS2131) in county *c*'s total self-employment in the beginning of a 3-year period, and $SE\_NG_{cnt-3,t}$ is the national self-employment growth rate in industry *n* between years *t-3* and *t*. We include a first difference of the SE industry mix variable, ΔSE_IndMix_c=$SE\_IndMix_{ct} - SE\_IndMix_{ct-3}$, and a first difference of the industry mix variable calculated separately for WS employment in our models.

In addition to these variables, other controls include a natural logarithm of 1980 population to reflect agglomeration effects that may nourish entrepreneurship via more market opportunities and may be potentially related to energy development and future population growth. We also include human capital measures approximated by educational attainment (the share of the adult population with at least 4 years of college and the share of the adult population with only high school diploma in 1990). Lagged industry composition effects are accounted for by inclusion of 1990 employment shares in manufacturing and agriculture. Finally, our models include the 1990 unemployment rate to account for the effects of past economic conditions that may influence future SE rates as suggested by the necessity entrepreneurship perspective (Low, Henderson, & Weiler, 2005). All models include time-period dummies, θ_t.

We estimate equation (1) using the SUR procedure for total SE, SE in tradable and SE in non-tradable industries and 11 individual sectors (see footnote 4) separately for nonmetro and metro counties. We then repeat the analysis for WS employment. SUR is employed because shocks in one sector may affect the residuals in other sectors. We define tradable industries as agriculture, mining (except NAICS2111 and NAICS2131), and manufacturing industries, which usually sell their products within 500 miles of the manufacturing facility. This definition follows Allcott and Keniston (2014) who divide manufacturing into tradable and non-tradable segments based on the distance adjustment elasticity (DAE) above 0.8 as defined in Holmes and Stevens (2014). Holmes and Stevens use 6-digit NAICS codes whereas our data are at the 4-digit NAICS level. We, thus, calculate shares of tradable and non-tradable 6-digit NAICS industries in the corresponding 4-digit NAICS industries using the 2000 County Business Patterns tables from the US Census Bureau. We then use these shares to divide employment in manufacturing into tradable and non-tradable. Appendix Table 1A displays the shares. The list of non-tradable industries includes manufacturing industries with DAE below 0.8, construction, retail, services, finance, insurance and real estate, government, transportation and warehousing.

All variables, except for educational attainment, 1990 unemployment rate, and 1985 mining share are calculated from a proprietary data set acquired from Economic Modeling Specialists Intl. (EMSI). The data contain information on county employment and earnings disaggregated at the 4-digit NAICS level and EMSI class of worker (COW). Our analysis focuses on Class of Worker 3, which captures those who are primarily self-employed, whereas 'marginal' proprietors such as part-time consultants or board of directors members are a part of Class of Worker 4. This is an advantage of the EMSI data because they provide a more accurate view of how *formal* SE is affected compared to previous studies[8]. Many studies have successfully used the EMSI data (Betz et al., 2015; Dorfman, Partridge, & Galloway, 2011; Fallah, Partridge, & Olfert, 2011; Fallah, Partridge, & Rickman, 2014; Nolan, Morrison, Kumar, Galloway, & Cordes, 2011). EMSI's breakdown of county employment by 4-digit NAICS codes is especially important for a more precise measure of oil- and gas-extraction, as well as for other variables including the industry mix terms because detailed publicly available county-level data are often suppressed for many industries for confidentiality reasons. EMSI aggregates several government data sources to estimate employment if it is suppressed.[9] We supplement the EMSI data set with information from the US Census Bureau (education measures), the US Bureau of Labor Statistics (unemployment rates), the US Energy Information Administration, geospatial files provided by the US Energy Information Administration[10] and US Geological Survey geospatial files (for instruments

[8] The US Bureau of Economic Analysis (BEA), a more common data source for the study of self-employment, reports all proprietors including those with a small fraction of their income through SE.
[9] In deriving their data, EMSI uses several government sources such as the Bureau of Economic Analysis REIS data, *County Business Patterns,* and *Quarterly Census in Employment and Wages.* Dorfman et al. (2011) provide more details of EMSI's process for deriving the employment figures.
[10] http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/maps/maps.htm#geodata

used in the sensitivity analysis section).[11] Appendix Table 2A shows summary statistics for all variables.

Estimation results and discussion

Table 1 presents main estimation results. It shows the effect of expansion in the oil and gas sector and the legacy of mining, as well as of being located on an oil or gas play, on SE controlling for other factors. We estimate three models for each subsample using a parsimonious specification (Model I) that includes only Δ*EnVar* and *Mining85,* followed by stepwise inclusion of other energy explanatory variables to assess robustness (Models II and III). The left panel of Table 1 contains the results for the nonmetro subsample and the right panel contains the results for the metro subsample. The estimation coefficients for the main energy variable show employment multipliers, i.e. how many new self-employment (in Table 1) or paid employment (in Table 2) jobs an average nonmetro and metro county may expect to receive as a result of one additional job created by the oil and gas sector.

According to Table 1, recent expansion of the oil and gas industry had statistically significant effects on self-employment in nonmetropolitan counties. This finding is unsurprising considering the *relatively* larger share (or impact) of the energy expansion in the nonmetro areas, in which oil and gas booms tend to have larger impacts on smaller nonmetro economies. Besides, SE accounts for a larger share of nonmetro employment on average (Henderson, Low, & Weiler, 2007). For instance, in the oil and gas industry during the 2001-2013 period, 3.8% and 3.1% of the jobs were held by self-employed in nonmetro and metro counties respectively.

Table 1. SUR estimation results for total self-employment

	Model I	Model II	Model III	Model I	Model II	Model III
	Non-metropolitan counties			**Metropolitan counties**		
Δ*EnVar*	9.7e-03 (1.18)	.022** (2.45)	.02** (2.23)	-6.3e-03 (-0.27)	-.014 (-0.60)	-.015 (-0.64)
Δ*EnVar squared*		-1.2e-03*** (-3.56)	-1.4e-03*** (-3.97)		3.6e-03* (1.86)	3.1e-03 (1.59)
Oil dummy			.37*** (2.99)			.22 (1.05)
Gas dummy			.1 (1.40)			.027 (0.37)
Mining85	1.9e-03	3.7e-03	9.0e-04	-1.1e-03	-3.7e-03	-4.7e-03

[11] http://certmapper.cr.usgs.gov/geoportal/catalog/search/resource/details.page?uuid=%7B985D2AB7-B159-46C2-BD58-99EC3E366C4F%7D

	(0.54)	(1.04)	(0.24)	(-0.18)	(-0.57)	(-0.72)
ΔSE*IndMix*	1.3*** (23.85)	1.3*** (23.95)	1.3*** (23.87)	1.5*** (24.15)	1.5*** (24.12)	1.5*** (24.13)
ΔWS*IndMix*	.036*** (4.56)	.035*** (4.49)	.035*** (4.47)	-.017 (-1.58)	-.016 (-1.56)	-.016 (-1.56)
Manuf share 90	-.013* (-1.80)	-.012* (-1.71)	-9.9e-03 (-1.41)	-5.2e-03 (-0.64)	-5.3e-03 (-0.64)	-5.0e-03 (-0.61)
Agri share 90	.033*** (2.93)	.033*** (3.00)	.032*** (2.90)	.043*** (3.08)	.042*** (2.98)	.042*** (2.96)
HS only 90	5.6e-03 (1.58)	5.2e-03 (1.46)	6.0e-03 (1.63)	9.5e-03** (2.01)	9.6e-03** (2.04)	9.7e-03* (1.95)
BA degree 90	.016** (2.05)	.016** (2.14)	.018** (2.33)	.012 (1.54)	.012 (1.52)	.012 (1.52)
lnPop 80	-.087*** (-2.68)	-.091*** (-2.81)	-.097*** (-2.97)	.018 (0.70)	.019 (0.75)	.019 (0.72)
Unemployment 90	-.019** (-2.48)	-.019** (-2.57)	-.019** (-2.51)	-9.0e-03 (-0.79)	-8.0e-03 (-0.70)	-8.2e-03 (-0.71)
Constant	.88** (2.12)	.92** (2.24)	.92** (2.20)	-.35 (-0.87)	-.37 (-0.91)	-.37 (-0.89)
R^2	0.262	0.264	0.265	0.394	0.395	0.395

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; number of observations is 5,958 in the nonmetro subsample and 3,117 in the metro subsample.

Several important results follow from Table 1. First, the coefficient on the energy explanatory variable of around .02 in Models II and III in the nonmetro sample suggests that for every 100 jobs exogenously created in a local economy by the oil and gas sector two additional SE jobs are added. This means (taking into account that 3.8% of workers in NAICS2111 and NAICS2131 are self-employed) that close to two net self-employment jobs are destroyed in other industries as a result of energy sector expansion after controlling for the legacy and endowment effects. This crowding out is even bigger in the counties with greater growth in the oil and gas industries as evidenced by the negative and statistically significant coefficient on the squared energy employment term. For example, when evaluated at the mean value of Δ*EnVar* in nonmetro counties with at least 0.5% energy employment share,[12] a 5.1% (one standard deviation) increase in oil and gas employment is associated with a 0.1% SE growth, whereas 0.2% SE growth is expected given the 3.8% average share of self-employed in the oil and gas industry. This indicates that in oil and gas extracting counties roughly 0.1% of self-employed growth is crowded out by each 5% growth in energy sector employment. Location on a primarily oil play, however, is associated with faster nonmetro SE growth. Second, in contrast to

[12] Estimation coefficients in the metro sample are insignificant, therefore we calculate average expected changes for the nonmetro sample only.

the previous studies (e.g., Betz et al., 2015), the insignificant 1985 mining share coefficients suggest that a historic legacy of mining is not statistically related to future SE growth.

Perhaps more importantly, demand shocks in the rest of the economy are a strong predictor of performance. In nonmetro counties, demand shocks in both the SE and WS parts of the local economy are associated with greater self-employment growth. For example, the 1.3 *ΔSEIndMix* coefficient suggests that when favorable economic conditions in the SE part of the national economy are expected to increase local self-employment by 1%, SE in nonmetro counties increases on average by 1.3% (adding 0.3% extra SE job growth through multiplier effects), while favorable economic conditions in the paid segment of the national economy adds .035% to the SE growth. SE in metro counties, on the other hand, is slightly more positively sensitive to SE demand shocks but statistically not for WS demand shocks. Overall, relative to average, growth in the energy sector is *crowding out* growth in SE, suggesting that the recent energy boom may be reducing long-term growth in affected regions by dampening the share of local entrepreneurship.

We now compare the effects of the recent US shale energy sector expansion on county-level SE with the effects on county-level wage and salary employment growth. Table 2 reports estimation results. First, the energy employment growth coefficient of 1 in the nonmetro models suggests that there are only modest spillovers (about 4 jobs per each 100 new jobs in the energy sector since 3.8% of energy workers are self-employed) into nonmetro WS employment with the inverted U-shape relationship between energy employment growth and paid employment growth. In metro counties, to the contrary, expanding oil and gas employment appears to crowd out WS employment with every 100 new energy jobs displacing about 11 WS positions in other industries[13]. Second, counties that specialized in mining in 1985 tend to have faster growth in WS employment decades later regardless of their rural or urban status. Finally, the effects of both SE and WS exogenous demand shocks (industry mix terms Table 2) are positive and strongly

[13] The 0.86 coefficient on the energy variable in the right panel of Table 2 implies that with every 100 jobs added in the oil and gas industries, an average metro county ends up with 86 jobs; since out of the 100 added energy jobs on average 3 are self-employed workers, crowding out of the paid employment amounts to 11 WS jobs.

significant with SE demand shocks having a larger impact on WS growth in the metro sample. This latter finding is in line with Tsvetkova et al. (forthcoming) who find that at the margin, total employment responds more to growth in self-employment than to growth in WS employment.

Table 2. SUR estimation results for total wage and salary employment

	Model I	Model II	Model III	Model I	Model II	Model III
	Non-metropolitan counties			**Metropolitan counties**		
Δ*EnVar*	1***	1***	1***	.86***	.86***	.86***
	(20.25)	(19.34)	(19.04)	(5.84)	(5.77)	(5.72)
Δ*EnVar squared*		-3.4e-03	-4.4e-03**		-1.4e-03	-5.0e-03
		(-1.61)	(-2.07)		(-0.12)	(-0.40)
Oil dummy			2.2***			1.8
			(3.00)			(1.32)
Gas dummy			-.42			-.36
			(-0.94)			(-0.78)
Mining85	.062***	.067***	.06***	.079**	.08**	.078*
	(2.84)	(3.05)	(2.64)	(1.98)	(1.96)	(1.90)
ΔSE*IndMix*	1.3***	1.3***	1.3***	2***	2***	2***
	(3.83)	(3.87)	(3.78)	(5.03)	(5.03)	(5.04)
ΔWS*IndMix*	1.5***	1.5***	1.5***	1.3***	1.3***	1.3***
	(30.43)	(30.40)	(30.36)	(19.00)	(19.00)	(19.00)
Manuf share 90	-.059	-.057	-.054	.021	.021	.025
	(-1.39)	(-1.35)	(-1.26)	(0.41)	(0.41)	(0.48)
Agri share 90	.14**	.14**	.13*	.27***	.27***	.26***
	(2.10)	(2.13)	(1.87)	(3.04)	(3.04)	(2.89)
HS only 90	.015	.014	.029	-.018	-.018	-7.1e-03
	(0.71)	(0.66)	(1.29)	(-0.61)	(-0.61)	(-0.23)
BA degree 90	.045	.047	.053	-2.9e-03	-2.9e-03	4.1e-03
	(0.98)	(1.02)	(1.15)	(-0.06)	(-0.06)	(0.08)
lnPop 80	-.21	-.22	-.21	.37**	.36**	.37**
	(-1.03)	(-1.09)	(-1.06)	(2.23)	(2.23)	(2.25)
Unemployment 90	-.022	-.024	-8.4e-03	-.015	-.016	-5.2e-03
	(-0.49)	(-0.53)	(-0.18)	(-0.21)	(-0.22)	(-0.07)
Constant	-.39	-.26	-.92	-4.9*	-4.9*	-5.4**
	(-0.16)	(-0.10)	(-0.36)	(-1.90)	(-1.89)	(-2.06)
R^2	0.364	0.364	0.365	0.505	0.505	0.506

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; number of observations is 5,958 in the nonmetro subsample and 3,117 in the metro subsample.

To further probe into the distribution of the oil and gas industry expansion effects across various sectors, we repeat the analysis for SE and WS employment growth in tradable and non-tradable industries. Table 3 presents the estimation results. Although the results seem to be weaker, perhaps due to the increasing noise in the data as we delve into finer detail, they generally imply that the energy sector is crowding out SE growth in the non-tradable sector, potentially confirming the hypothesis that those who were previously self-employed or considering self-employment prefer being employed in the energy sector or elsewhere during the boom. In contrast, energy sector expansion promotes non-tradable paid employment growth but has no effect on either tradable or non-tradable sectors in the metro counties. A legacy of mining is weakly supports future paid employment growth in all models except for tradable employment in metro counties, whereas location above oil play stimulates both SE and WS employment growth in nonmetro non-tradable industries. The positive and significant *ΔSEIndMix* and *ΔWSIndMix* coefficients indicate that both the traded and nontraded sectors are (mostly) positively affected by exogenous demand shocks.

Table 3. SUR estimation results for self-employment and wage and salary employment in tradable and non-tradable sectors

	Self-employment				**Wage and salary employment**			
	Tradable	Non-tradable	Tradable	Non-tradable	Tradable	Non-tradable	Tradable	Non-tradable
	Nonmetro counties		**Metro counties**		**Nonmetro counties**		**Metro counties**	
Δ*EnVar*	2.8e-03 (1.32)	5.9e-03 (0.67)	6.8e-04 (0.30)	-.04* (-1.72)	3.6e-03 (0.16)	.22*** (4.49)	-.044 (-0.81)	.055 (0.39)
Δ*EnVar squared*	-5.8e-05 (-0.70)	-1.2e-03*** (-3.52)	6.6e-05 (0.35)	2.1e-03 (1.10)	-1.1e-04 (-0.13)	1.4e-03 (0.74)	1.0e-03 (0.23)	-4.1e-03 (-0.35)
Oil dummy	-.024 (-0.84)	.39*** (3.25)	-9.6e-03 (-0.47)	.23 (1.11)	-.11 (-0.34)	2.4*** (3.62)	.15 (0.31)	1.7 (1.38)
Gas dummy	-.01 (-0.58)	.11 (1.54)	-2.1e-03 (-0.29)	.03 (0.42)	-.26 (-1.42)	-.13 (-0.31)	-.22 (-1.31)	-.14 (-0.32)
Mining85	-1.1e-04 (-0.12)	1.4e-03 (0.37)	-9.4e-05 (-0.15)	-2.6e-03 (-0.40)	.017* (1.82)	.036* (1.74)	-5.5e-03 (-0.36)	.08** (2.08)
ΔSE*IndMix*	.27*** (20.58)	1*** (19.00)	.052*** (8.62)	1.4*** (23.74)	-.2 (-1.41)	1.5*** (4.91)	.3** (2.06)	1.7*** (4.64)
ΔWS*IndMix*	8.3e-03*** (4.42)	.03*** (3.90)	2.7e-04 (0.27)	-.016 (-1.53)	.6*** (30.01)	.86*** (19.81)	.38*** (15.68)	.88*** (14.25)
R^2	0.073	0.238	0.044	0.393	0.232	0.222	0.246	0.422

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; number of observations is 5,958 in the nonmetro subsample and 3,117 in the metro subsample; all models include a full set of controls and time period dummies (see Tables 1 and 2).

Sensitivity analysis

A community's proclivity to allow oil and gas extraction may be related to a number of factors that, in turn, impact economic performance and job creation. Generally, given the relatively short period under consideration, we expect that factors such as local business climate and regulatory environment to be generally time invariant and accounted for by the county fixed effect. However, if there are omitted time-varying factors that correlate with both the explanatory and dependent variables, we cannot entirely rule out the possibility of endogeneity. For instance, aside from common national business cycle effects captured in the time fixed effects, if there are changes in local attitudes toward energy development our estimation approach might be unable to account for potential endogeneity. To test if this is a valid concern, we run the series of diagnostic tests with the Wu-Hausman test of endogeneity results reported in Tables 4 and 5 below. The test results suggest that endogeneity is a valid concern for the SE models, whereas it is not statistically significant in the WS employment models.

To address any endogeneity and as a test of the sensitivity of the results reported above, we use an instrumental variable (IV) approach following past studies, though with a wider set of instruments (Brown, 2014; Weber, 2012, 2014; Weinstein, 2014). Instrumenting for the energy employment growth variables also allows addressing the measurement error issues in assessing energy dependency. For this reason we repeat the analysis using the IV approach for both SE and WS models, although in the latter case the Wu-Hausman test rejects the null hypothesis of the presence of endogeneity. We instrument our main energy explanatory variables, the change in growth rate of oil and gas employment and its square with a set of instruments[14] consisting of four measures that approximate thickness of oil and gas shale deposits, recoverable tight oil and recoverable shale gas reserves and the oil and gas drilling intensity in the 1980s at a county level. Appendix B provides more details on the calculation of the instruments. The instrument set consists of four instruments and their interactions with time periods to account for time-varying nature of the endogeneity-introducing factors such as oil price hikes or local economic conditions that may change local policymakers' and/or energy companies' willingness to engage in energy development in a given jurisdiction.

Table 4 displays IV estimation respective results for total self-employment as well as self-employment in tradable and non-tradable industries using the full model (Model III in Tables 1 and 2). Table 5 does the same for WS employment. After the Wu-Hausman endogeneity test results, the last three rows in the tables below show diagnostics for the instruments' performance. In general the chosen instruments are strong in the first-stage in all cases except for the instrumenting $\Delta \mathit{EnVarSq}$ in the metropolitan sample. In the SE models, all equations are identified (instruments are not

[14] We developed five instruments based on historical oil and gas extraction and geological abundance of resources for this research and tested various combinations of these instruments. The four used in this paper give the best results in terms of model identification and instrument strength.

correlated with the error term) except for the tradable sector. In the WS models, the picture with identification is reversed with only the tradable sector models passing the over-identification test, although the absence of endogeneity in the WS equations suggests that the SUR results reported in Tables 1-3 should be more credible.

Table 4. IV estimation results for self-employment

	Total	Non-tradable	Tradable	Total	Non-tradable	Tradable
	Non-metropolitan counties			Metropolitan counties		
Δ*EnVar*	-.043* (-1.66)	-.085*** (-3.27)	.011* (1.78)	-.35*** (-4.24)	-.36*** (-4.47)	-.02** (-2.34)
Δ*EnVar squared*	-2.9e-04 (-0.23)	1.9e-04 (0.15)	-1.0e-04 (-0.33)	-.017 (-0.83)	-.014 (-0.68)	-4.5e-03** (-2.18)
Oil dummy	.42*** (2.75)	.48*** (3.18)	-.039 (-1.07)	.94* (1.72)	.84 (1.57)	.12** (2.12)
Gas dummy	.094 (1.30)	.1 (1.39)	-9.0e-03 (-0.52)	.032 (0.40)	.034 (0.45)	-1.7e-03 (-0.21)
Mining85	1.3e-03 (0.32)	2.2e-03 (0.54)	-3.1e-04 (-0.32)	.017 (1.12)	.016 (1.08)	3.4e-03** (2.25)
ΔSE*IndMix*	1.3*** (23.38)	1*** (18.35)	.27*** (20.59)	1.5*** (22.63)	1.5*** (22.41)	.056*** (8.16)
ΔWS*IndMix*	.032*** (4.01)	.026*** (3.27)	8.7e-03*** (4.56)	-.025** (-2.16)	-.023** (-2.11)	-5.3e-04 (-0.45)
Wu-Hausman test	0.04	0.00	0.01	0.00	0.00	0.00
First-stage F (Δ*EnVar*)	62.33	107.11	107.11	25.07	49.19	49.19
First-stage F (Δ*EnVarSq*)	38.24	23.56	23.56	2.64	5.07	5.07
Overid test	0.171	0.432	0.000	0.971	0.767	0.017

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; number of observations is 5,958 in the nonmetro subsample and 3,117 in the metro subsample; all models include a full set of controls and time period dummies (see Tables 1 and 2).

In interpreting the findings presented in Table 4, the tradable sector results should be cautiously interpreted due to the overidentification test results. For the total nonmetro SE results across all three models, the IV results are consistent with the OLS findings that energy sector expansion during the 2001-2013 period had a crowding out effect on SE, which was mostly observed in the non-tradable industries. The other explanatory variables results are virtually identical to those reported in Table 1. In contrast to the SUR results reported in Table 1, however, the IV estimation suggests that the SE job destruction by the growing oil and gas industry is not limited to nonmetro counties but is a consistent story across all county types. Given the evidence of endogeneity in all SE models, strong instruments and identification of the SE models for total and non-tradable employment in the metro subsample, the estimation results of Table 4 may be preferable, though the SUR and IV results are very comparable in general.

Table 5. IV estimation results for wage and salary employment

	Total	Non-tradable	Tradable	Total	Non-tradable	Tradable
	Non-metropolitan counties			**Metropolitan counties**		
Δ*EnVar*	1.2*** (7.42)	.29** (2.01)	.034 (0.52)	.67 (1.35)	-.12 (-0.27)	-.049 (-0.27)
Δ*EnVar squared*	-9.4e-03 (-1.22)	-4.0e-04 (-0.06)	-2.3e-03 (-0.73)	-3.7e-03 (-0.03)	-3.8e-03 (-0.03)	-3.1e-03 (-0.07)
Oil dummy	2.3** (2.49)	2.4*** (2.91)	-7.8e-03 (-0.02)	1.9 (0.57)	1.8 (0.60)	.25 (0.21)
Gas dummy	-.4 (-0.91)	-.12 (-0.30)	-.26 (-1.41)	-.36 (-0.78)	-.14 (-0.32)	-.22 (-1.31)
Mining85	.063** (2.50)	.036 (1.60)	.02* (1.87)	.082 (0.92)	.084 (1.01)	-2.7e-03 (-0.08)
ΔSE*IndMix*	1.3*** (3.86)	1.5*** (4.93)	-.19 (-1.34)	2*** (4.91)	1.7*** (4.52)	.3** (2.03)
ΔWS*IndMix*	1.5*** (29.68)	.86*** (19.38)	.6*** (29.26)	1.3*** (18.57)	.88*** (13.91)	.38*** (15.35)
Wu-Hausman test	0.58	0.39	0.68	0.92	0.66	1.00
First-stage F (Δ*EnVar*)	62.33	107.11	107.11	25.07	49.19	49.19
First-stage F (Δ*EnVarSq*)	38.24	23.56	23.56	2.64	5.07	5.07
Overid test	0.001	0.053	0.266	0.002	0.071	0.618

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; number of observations is 5,958 in the nonmetro subsample and 3,117 in the metro subsample; all models include a full set of controls and time period dummies (see Tables 1 and 2).

Table 5 presents IV estimation results for paid employment for completeness. There is no evidence of endogeneity in this set of models and many models, although containing strong instruments, do not pass the over-identification tests. Thus, the results should be cautiously interpreted. In general they suggest weaker energy effects on employment than in the SUR models.

Conclusion

Self-employment is emerging as an important determinant of regional economic prosperity. This brings the question of how SE growth is affected by the local environment, with the impact of local factors being reinforced by the self-propelling nature of self-employment. Against this backdrop, this study investigates the effects of recent US oil and gas industry boom on local economies by assessing and contracting the impact of energy sector expansion on self-employment and paid employment growth. We also compare the effects of growing oil and gas industries to the effects of the demand shocks in the rest of the economy in order to draw general policy recommendations about the relative role of entrepreneurship/small business development in describing the natural resource curse and the relative importance of SE multiplier effects versus corresponding WS effects.

Overall, our results support previous research that studies the impact of resource (coal) heritage on entrepreneurship (Betz et al., 2015; Glaeser et al., 2015), though we are the first to explicitly examine this for energy boomtowns. Generally, the results support the findings that natural resource extraction is associated with crowding-out entrepreneurship, which implies weaker long-term growth. This suggests that perhaps at least one underlying mechanism of the resource curse is at work in US regions despite the notion that more advanced American institutions should help avoid the resource curse[15]. The crowding out of entrepreneurship, especially in rural areas that usually have limited opportunities for growth, is likely to manifest itself in deeper decline and slower growth when energy booms turn into bust. These findings are of particular importance to local policymakers in affected areas who should consider purposeful attempts to redistribute the windfall of revenues from oil and gas development into diversification of their economies and creating other engines of sustained growth such as small business development. Likewise, these results cast doubt on the ability of natural resource development to trigger the "big push" effect that should support further development and creation of agglomeration economies.

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[15] Resent work by Rickman and co-authors (Rickman et al., 2017) documents presence of another potential mechanism of the resource curse in the US, namely decreased educational attainment in shale-rich states of North Dakota, Montana and West Virginia.

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Appendix A

Table 1A. Tradable and non-tradable manufacturing industries (% of total employment)

NAICS	Tradable	Non-tradable	NAICS	Tradable	Non-tradable
3111	0.000	1.000	3311	1.000	0.000
3112	0.453	0.547	3312	0.638	0.362
3113	0.917	0.083	3313	0.625	0.375
3114	0.899	0.101	3314	0.971	0.029
3115	0.419	0.581	3315	1.000	0.000
3116	0.000	1.000	3321	0.318	0.682
3117	1.000	0.000	3322	1.000	0.000
3118	0.173	0.827	3323	0.000	1.000
3119	0.501	0.499	3324	0.256	0.744
3121	0.219	0.781	3325	1.000	0.000
3122	0.857	0.143	3326	1.000	0.000
3131	1.000	0.000	3327	0.300	0.700
3132	1.000	0.000	3328	0.000	1.000
3133	1.000	0.000	3329	1.000	0.000
3141	1.000	0.000	3331	1.000	0.000
3149	1.000	0.000	3332	1.000	0.000
3151	1.000	0.000	3333	1.000	0.000
3152	0.900	0.100	3334	1.000	0.000
3159	1.000	0.000	3335	1.000	0.000
3161	1.000	0.000	3336	1.000	0.000
3162	1.000	0.000	3339	1.000	0.000
3169	1.000	0.000	3341	1.000	0.000
3211	0.000	1.000	3342	1.000	0.000
3212	0.201	0.799	3343	1.000	0.000
3219	0.127	0.873	3344	1.000	0.000
3221	0.634	0.366	3345	1.000	0.000
3222	0.274	0.726	3346	0.926	0.074
3231	0.292	0.708	3351	1.000	0.000
3241	0.000	1.000	3352	1.000	0.000
3251	0.881	0.119	3353	1.000	0.000
3252	1.000	0.000	3359	1.000	0.000
3253	0.402	0.598	3361	1.000	0.000
3254	1.000	0.000	3362	0.500	0.500
3255	0.304	0.696	3363	1.000	0.000
3256	1.000	0.000	3364	1.000	0.000
3259	0.567	0.433	3365	1.000	0.000
3261	0.736	0.264	3366	1.000	0.000
3262	0.957	0.043	3369	1.000	0.000
3271	0.782	0.218	3371	0.478	0.522
3272	0.381	0.619	3372	1.000	0.000
3273	0.000	1.000	3379	0.000	1.000
3274	0.000	1.000	3391	1.000	0.000
3279	0.242	0.758	3399	0.983	0.017

Table 2A. Summary statistics for the variables by sample

Variable	Nonmetro counties				Metro counties			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Dependent variables								
ΔSE Total emp growth	-0.44	1.78	-15.34	11.48	-0.55	1.54	-26.41	15.04
ΔSE Tradable emp growth	-0.01	0.38	-17.46	8.79	-0.01	0.12	-1.55	1.30
ΔSE Non-tradable emp growth	-0.43	1.73	-14.03	10.91	-0.54	1.50	-25.78	14.94
ΔWS Total emp growth	0.54	11.67	-69.26	75.26	0.39	10.74	-98.66	106.08
ΔWS Tradable emp growth	0.54	4.42	-49.75	42.80	0.56	3.18	-30.25	35.10
ΔWS Non-tradable emp growth	-0.11	9.56	-68.04	72.10	-0.21	9.24	-96.67	104.90
Explanatory variables								
ΔEnergy variable	0.15	2.45	-35.29	57.12	0.05	0.94	-18.18	21.68
ΔEnergy variable squared	6.02	63.88	0.00	3,263	0.88	11.74	0.00	470.12
Oil dummy	0.03	0.18	0.00	1.00	0.01	0.11	0.00	1.00
Gas dummy	0.10	0.30	0.00	1.00	0.11	0.31	0.00	1.00
ΔSE Industry mix	-0.56	0.73	-4.77	2.00	-0.50	0.69	-4.14	0.78
ΔWS Industry mix	0.97	6.88	-22.37	29.39	1.19	7.72	-17.44	25.02
Mining85	3.01	6.29	0.00	58.75	1.40	3.58	0.00	48.05
Control variables								
Share of adults w HS only, 1990	33.29	6.20	14.77	50.24	33.29	6.20	14.77	50.24
Share of adults w BA, 1990	10.76	4.87	2.51	28.90	10.76	4.87	2.51	28.90
Manufacturing share, 1990	4.78	3.75	0.09	20.60	4.82	3.05	0.05	20.18
Agriculture share, 1990	4.73	2.94	0.01	19.26	2.44	2.44	0.00	13.63
Population (ln), 1980	11.11	1.34	7.25	15.83	11.11	1.34	7.25	15.83
Unemployment, 1990	5.67	2.25	1.65	25.50	5.67	2.25	1.65	25.50
Instruments								
Thickness	0.0004	0.0036	0.0000	0.1234	0.0002	0.0021	0.0000	0.0548
Gas	0.0003	0.0011	0.0000	0.0181	0.0003	0.0009	0.0000	0.0069
Oil	0.0002	0.0014	0.0000	0.0400	0.0006	0.0084	0.0000	0.1994
Miles	0.0004	0.0008	0.0000	0.0097	0.0003	0.0007	0.0000	0.0075
Observations	5,958				3,117			

Instruments used in this study are described below.

1. *Thickness* is a measure of the thickness of a shale play under a county standardized by the sum of such measures for all counties in the nation:

$$Thickness_c = {T_s A_{cs}}/{\sum_c \sum_s T_s A_{cs}}$$

where subscript *c* denotes county, T_s is the thickness of shale play *s,* A_{cs} is the area of county *c* over shale play s;

2. *Oil* is a measure of the projected recoverable shale oil reserves under a county standardized by recoverable shale oil reserves in the nation:

$$Oil_c = {O_s \% A_{cs}}/{\sum_c \sum_s O_s \% A_{cs}}$$

where subscripts are identical to the above, O_s is the projected recoverable oil in shale play *s,* $\%A_{cs}$ is the fraction of a county *c*'s area over shale play *s;*

3. *Gas* is a measure of the projected recoverable shale gas reserves under a county, which is calculated identically to *Oil* but for shale gas;
4. *Miles* is a measure of drilling intensity in a county in the 1980s standardized by the drilling intensity in the nation

$$Miles_c = {MW_c}/{\sum_c MW_c}$$

where MW_c is the total number of miles in county *c* that had at least one oil or gas well in the 1980.

In addition to the four instruments described above, the set of instruments used in each model include interaction of *Thickness*, *Oil*, *Gas* and *Miles* with time period dummy variables in order to factor out time-varying endogeneity.