Follow the Money: How Does the Income Flow After an Energy Boom

Weinstein, Amanda and Partridge, Mark and Tsvetkova, Alexandra

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Amanda L. Weinstein[1], Mark D. Partridge[2] and Alexandra Tsvetkova[3]

[1]University of Akron
Department of Economics
Email: aweinstein@uakron.edu

[2]The Ohio State University
Jinan University
Urban Studies and Regional Science, Gran Sasso Science Institute, L'Aquila, Italy
Email: partridge.27@osu.edu

[3]The Ohio State University
Email: tsvetkova.1@osu.edu

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Abstract

Many U.S. towns reportedly boomed after new technologies in oil and gas extraction, particularly improved hydraulic fracturing, led to rapid development of shale resources. Recent research on the expected economic impact focused on the employment multipliers associated with new oil and gas jobs. Instead, our focus is the impact of oil and gas industry growth on local earnings while paying attention to the distributional effects and assessing how much income seeps out due to the peculiarities of the industry. Our estimation results suggest that oil and gas earnings multipliers are relatively modest and mostly similar to oil and gas employment multipliers, with relatively large shares of the earnings leaving the county on average. Likewise, oil and gas multipliers tend to be smaller or comparable to the estimated multipliers for equal-sized shocks in the rest of the economy, suggesting that oil and gas is not a special industry case. Given the high wages in the sector and the large royalty payments that can go to landowners, these results may be surprising.

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1. Introduction

Innovations in oil and gas extraction, specifically hydraulic fracturing and horizontal drilling, have changed the face of global energy markets. The so-called “shale revolution” transformed energy markets while areas that were previously economically unviable for energy development became home to drilling activity. As U.S. oil and gas production from shale increased, so too did direct oil and gas employment and total earnings in most states. Between 2001 and 2014, employment and total earnings in Oil and Gas Extraction (NAICS2111) and Support Activities for Mining (NAICS2131) industries has grown in 43 states with growth exceeding 100% in 25 states for employment and in 28 states for total earnings (Appendix Table1A). Hydraulic fracturing is even credited with helping to keep CO_2 emissions below 2005 levels due to enhanced use of natural gas instead of coal (EIA, 2014). The shale revolution is touted by industry supporters as providing a key source of jobs for both the locally affected communities and the nation as a whole.

Despite the hype, an emerging academic consensus is that modern energy development is associated with moderate local economic impacts (Brown, 2014; Weinstein, 2014; Munasib and Rickman, 2015). First, the oil and gas industry still encompasses a small share of the economy; during the shale boom, its share of total nonfarm employment in the US increased from 0.23% in 2001 to just 0.44% in 2014 (BEA), just as the recent boom subsided.[1] Second, the oil and gas industry is capital intensive and it appears that very recent innovations (especially automation) made an already productive industry even more productive (Krauss, 2017). Although higher productivity is undoubtedly good for overall economic efficiency, it also reduces the expected labor market impacts. Third, after wells are drilled and the shale is fractured, each well requires significantly fewer workers to continue production compared to the initial construction and drilling phases (Kelsey et al., 2016).

Recent research has predominantly focused on estimating the expected employment impacts from shale development. Less attention has been paid to the impacts of shale development on earnings and what share of these earnings remains in the local area. This paper fills this gap by estimating the effects of the recent growth in the oil and gas industry on total and average earnings in US counties. We also ask whether the impacts of oil and gas earnings differ from those of equal-sized shocks from all other industries in the economy. These are important issues because the ability of a resource boom to promote long-term prosperity (or, alternatively, to facilitate the development of a resource curse)

[1] Calculated using U.S. Bureau of Economic Analysis (BEA) nonfarm employment data. Oil and gas employment includes both oil and gas extraction and support activities for *all* mining, which might slightly overstate the size of the oil and gas sector.

depends on how much of the income from an expanding energy sector remains local.

One reason for the lack of research is that it requires disaggregated data for the oil and gas industry to make accurate derivations, which is typically suppressed in publicly available sources for confidentiality, especially in sparsely populated counties where firm identification may be easier. We use detailed annual oil and gas employment and earnings data at the county level from 2001 to 2013 provided by Economic Modeling Specialists Intl. (EMSI) to measure the impacts of shale development.

Our base findings suggest that for every dollar increase in oil and gas earnings, counties should expect an increase of about 30 cents in all other industries (a multiplier of 1.3) in the nonmetro sample and an increase of about 10 cents (a multiplier of 1.1) in the metro sample. The earnings multipliers vary across space with larger impacts observed in areas that mostly did not have appropriate supportive infrastructure already in place. The effects also differ between tradable and non-tradable industries with some evidence of crowding out of nonmetro tradable total earnings, consistent with the Dutch Disease phenomenon. By comparison, the impact of oil and gas shocks tends to be similar (or somewhat smaller) than the effects of equal-sized shocks in the rest of the economy suggesting that the oil and gas industry is not very different from an average industry. Perhaps our most important finding is that the added earnings that are a result of the expanding oil and gas industry mostly leave the locality they were generated in (perhaps due to the use of in-migrant workers), limiting the ability of local residents to benefit.

2. The relationship between resource endowment and earnings

The shale boom is a relatively recent phenomenon and our knowledge on the relationship between shale oil and gas extraction and earnings is very limited. It might be useful, however, to refer to the studies that looked at previous booms in the extraction of resources other than oil and gas. For example, Margo (1997) finds that the boom (and bust) of the 1840s gold rush in California left wages permanently higher. During the construction of the Trans-Alaska Pipeline in the 1970s (the world's largest privately financed construction project at the time), wages showed significant flexibility with construction experiencing higher wages in the short run but not the long run (Carrington, 1996). Although this resulted in most residents experiencing large income gains, higher prices offset the gains for workers in most industries other than construction. The demand shock also had adverse effects on many social welfare measures such as crime rates. Thus, many residents may have been left worse off.

Other research shows the impacts of resource booms and busts are not symmetric. In an analysis of the 1970s coal boom and subsequent bust in the 1980s, Black et al. (2005) found the short- and long-term wage impacts varied by sector. Although wages showed flexibility in both mining and non-mining sectors, migration did not eliminate the wage impacts. For mining, wages increased 27.3% during the boom and declined by only 9.7% during the bust. This was not the case for non-mining sectors where wages increased only 5.8% during the boom but decreased 9.3% during the bust. Similarly, Jacobsen and Parker (2014) examine the oil boom and bust of the 1970s and 1980s in the Rocky Mountain region. They find evidence of long run negative impacts, though their net present value calculations suggest that the increases in income during the boom outweigh the losses.

The relatively poor long-term economic outcomes for natural resource abundant areas have been termed the "natural resource curse." Supporting empirical evidence for the natural resource curse has been found at every level from countries (Sachs and Warner, 1995; Papyrakis and Gerlagh, 2004) to U.S. states (Papyrakis and Gerlagh, 2007; Freeman, 2009) and U.S. counties (Kilkenny and Partridge, 2009; James and Aadland, 2011; Jacobsen and Parker, 2014)[2]. Despite having higher levels of natural capital and a comparative advantage in extracting and exporting these resources, many of these areas don't appear to capitalize on such an advantage in the long run. By contrast, the export base hypothesis—which is similar to a modern mercantilist point of view—asserts that continued demand for these natural resources should lead to steady economic growth.

Various studies have assessed this somewhat surprising pattern and the transmissions channels leading to the resource curse. Poor institutions (especially across countries) have been attributed with corruption and conflict, rent-seeking behavior, bad policies and poor governance, underdeveloped financial and legal institutions, and less public investment (Gylfason, 2000; 2001; Papyrakis and Gerlagh, 2004; Mehlum et al., 2006; van der Ploeg, 2011; Kelsey et al., 2016). Natural resource development may crowd out other economic activities. The term "Dutch Disease" was coined after natural gas discoveries in the Netherlands led to wages being bid up and the appreciation of exchange rates negatively impacted manufacturing (Corden, 1984). Through higher real exchange rates or higher wages, other industries and entrepreneurs may not be able to compete in such as environment (Gylfason, 2000; 2001; Freeman, 2009; Betz et al., 2015; Sachs and Warner, 2001). The relatively high wages paid by

[2]There are, of course, exceptions. Some natural resource abundant regions seem to experience positive long-term economic outcomes (Alexeev and Conrad, 2009; Cavalcanti et al., 2011; Michaels, 2011). Jacobsen (2015) finds that housing prices and wages increase in almost all occupations in nonmetro areas that experience an energy boom. He concludes "there are many monetary 'winners' from energy development in local communities and very few losers" (pp. 3-4).

natural resource extraction industries to relatively low-skilled workers may also discourage or crowd out human capital investment leading to lower educational attainment and education investment (Gylfason, 2001; Black et al., 2005; Papyrakis and Gerlagh, 2007; van der Ploeg, 2011; Blanco and Grier, 2012).

The boom and bust cycle itself and the volatility associated with international commodity markets may be another reason for the natural resource curse (van der Ploeg and Poelhekke, 2009; Black et al., 2005; Gunton, 2003). Natural resource price volatility leads to volatility in revenues that are difficult to manage, leaving areas accustomed to higher expenditures unprepared to make cutbacks when the revenue windfall subsides. As areas become more dependent on natural resources, their economies become more volatile, which means that industries outside of the energy sector may be deterred to invest in such risky environments. The failure of resource-dependent regions to diversify economies stunts their growth prospects (Murshed & Serino, 2011; Gunton, 2003).

Previous academic research has focused on estimating employment multipliers associated with shale development with less attention paid to the impact on income and earnings.[3] Some academic research has examined the impact of the current shale boom on income and earnings, though none provide earnings multipliers. Using production data, Weber (2012) estimate that for every million dollars of gas produced in Colorado, Texas, or Wyoming counties between 1999 and 2007, total wage and salary income increased by $91,000. This would amount to about $568 million in the state of Colorado in 2007 (out of a total personal income of just over $155 billion).[4]

As shale development matures, however, the number of oil and gas workers per well or per million dollars of gas will likely decline as producing wells require fewer workers after construction, drilling, and hydraulic fracturing. Using oil and gas employment to measure the impact, Weinstein (2014) suggests that although the impact on employment growth is modest, the impact on earnings

[3] Industry-funded impact studies that tend to find larger expected effects suggested that shale development should boost local earnings considerably. For example, Kleinhenz (2011) estimated that wages in Ohio would increase by $12 billion by 2015 thanks to shale drilling activity. To put that number in perspective, Ohio's ***actual*** growth in total compensation in the oil and gas sector between 2010 (when the shale boom began in Ohio) and 2014 was $284 million. Though 2015 has not been reported in detail, total compensation in the mining industry as a whole (which is mostly oil and gas in Ohio) fell by $52 million, so it is clear that this prediction is off by a factor of about 50. Even North Dakota's total compensation in the mining sector (virtually all oil and gas) increased by only $2.4 billion from 2003 to 2014 (BEA). Although Kleinhenz' (2011) estimates for Ohio seem large (especially compared to North Dakota where the shale boom has been much more pronounced), they pale in comparison to recent estimates of the income impact for California. An industry funded study by the University of Southern California Global Energy Network (2013) estimated that shale development could increase California's personal income by $223 billion by 2020, or nearly 100 times larger than what *actually* happened in North Dakota.

[4] Calculated using USDA ERS production data for Colorado counties and U.S. EIA 2007 natural gas wellhead price for Colorado. Total wage and salary earnings are from the U.S. Bureau of Economic Analysis.

growth may be twice its relative size. Appendix Figures 1A and 2A show the increase in oil and gas employment and earnings, respectively. It is clear that the increase in earnings in the states most affected by shale oil and gas development is more dramatic than the employment increase. Higher earnings are likely to result from a number of factors such as an increase in earnings from newly created jobs including well-paid oil and gas jobs, indirect effects of lease and royalty payments to local landowners, and higher wages in other sectors as the labor market tightens. Conversely, Paredes et al. (2015) and Munasib and Rickman (2015) find that shale development did not significantly impact income or per capita income (respectively) in Pennsylvania, though Munasib and Rickman find that per capita income in North Dakota's oil and gas nonmetropolitan areas significantly increased. Munasib and Rickman's research focus on North Dakota, Pennsylvania, and Arkansas (some of the prominent oil and gas states) indicates that the impact of shale likely varies by region.

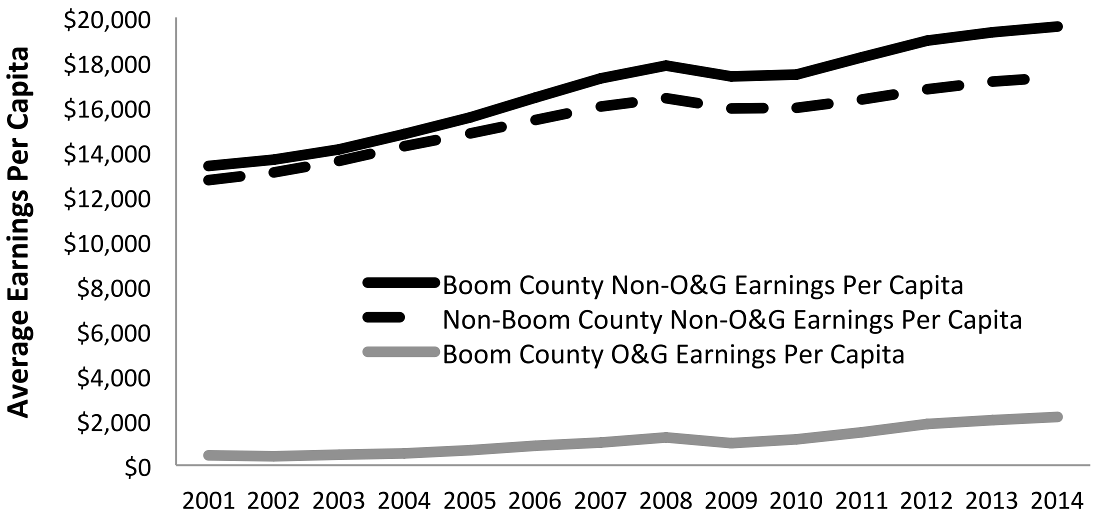
3. Empirical approach, data and variables

We use 2001-2013 detailed county level employment and earnings data from Economic Modeling Specialists Intl. (EMSI)[5] for 2,006 nonmetro and 1,055 metro counties in the lower 48 states. Figure 1 shows the increase in average total non-oil and gas per-capita earnings for shale boom counties compared to non-shale boom counties.[6] Shale boom counties also seem to experience faster growth in non-oil and gas earnings, suggesting positive net spillovers.

Figure 1. Growth in average total earnings per capita across counties

[5] We calculate the total *direct* oil and gas employment and earnings by summing the employment and earnings for NAICS industry code 2111 (Oil and Gas Extraction) and 2131 (Support Activities for Mining). EMSI uses several government sources (starting with the BLS *Quarterly Census of Employment and Wages*) and an algorithm to calculate values suppressed in publically available sources in a way that is consistent across industries and counties to sum to reported industry, state, and national totals. Tsvetkova and Partridge (2016) has a fuller discussion of the accuracy of EMSI oil and gas data.

[6] Oil and gas boom counties are defined using Weinstein's (2014) definition of any county in a shale booming state with at least a 10% increase in oil and gas employment and at least 20 additional oil and gas workers during the boom. The 20 additional worker minimum rules out places with economically insignificant changes in oil and gas employment even if the percentage point changes are large.



Source: EMSI Data.

To assess the effects of the oil and gas industry growth on local earnings we rely on a differencing strategy and use OLS as the main estimation approach in measuring the effects of this unexpected boom in oil and gas development. The differencing eliminates all constant unobservable county characteristics that can influence economic performance. Since in some cases, there is some evidence of endogeniety, we report instrumental variable (IV) estimation results in the sensitivity section. An IV approach also helps mitigate potential measurement issues. Equation (1) shows the empirical specification.

$$\Delta Y_c = \beta_0 + \beta_1 \Delta EnGr_c + \beta_2 \Delta WEnGr_c + \beta_3 Boom_c + \beta_4 \Delta IndMix_c + \boldsymbol{X\beta} + \theta_t + \varepsilon_c \quad (1)$$

where subscript *c* stands for a county and subscript *t* for a time period. Our main interest is in the earnings performance of the localities that experience energy expansion as compared to other areas, thus, we estimate Equation (1) for main two outcome variables, total earnings and average earnings (earnings per worker or EPW) in a county. To place our findings within the existing literature that mostly focuses on employment, we additionally estimate Equation (1) for total county employment. The dependent variable $\Delta Y_c = Y_{ict} - Y_{ict-3}$[7] is a first-differenced three-year growth in the dependent variable denoted by subscript *i* (total earnings, average earnings or employment). For example, if total earnings growth in a county was 2% between 2007 and 2010 and it was 5% between 2010 and 2013, the value of the dependent variable for this specific county is 3 (5%-2%).

[7] Percentage growth for, for instance, total earnings (*TotEarn*) is calculated in the following manner: $TotEarnGr=(TotEarn_{ct}-TotEarn_{ct-3})/TotEarn_{ct-3}*100$.

Our analysis focuses on total earnings, earnings per worker and total employment, however, we also assess the distribution of the energy development effects across sectors by examining the earnings and employment outcomes separately for tradable and non-tradable industries. We follow Tsvetkova and Partridge (2016) and define tradable industries as agriculture, mining (excluding NAICS2111 and NAICS2131) and manufacturing industries that are not a part of non-tradable sector. Non-tradable industries include utilities, construction, wholesale and retail trade, transport and warehousing, FIRE and other services, government and manufacturing industries that usually sell their products within approximately a 500-mile radius[8].

The main explanatory variable $\Delta EnGr = EnGr_{jct} - EnGr_{jct-3}$ is a first-differenced three year growth in county energy performance measured by two alternative outcomes *j* (NAICS2111 and NAICS2131 total earnings or total employment). It is calculated in the way identical to the dependent variables with the only difference that total county earnings or employment (not energy earning or employment) are used as the base in order to keep the scaling of the dependent and explanatory variables consistent. Because of this consistency, the β_1 coefficient can be interpreted as a multiplier in models that have total earnings and total employment as dependent variables.

The relative attractiveness of shale development may vary over time with the rise and fall of oil prices, ongoing technological change and other factors. Business-cycle effects may alter a region's willingness to accept shale development. These considerations may indicate a potential presence of endogeneity in our models that could bias the results. In order to mitigate these concerns, in addition to OLS estimation, we follow previous studies (e.g., Weber, 2012; Weber, 2014; Brown, 2014; Weinstein, 2014; Tsvetkova and Partridge, 2016) and use a set of measures to instrument for growth in oil and gas earnings (or employment). To this end, we developed five instruments that measure percent of a county area over a shale play, amount of recoverable shale gas, amount of recoverable tight oil, thickness of a shale play and intensity of drilling in the 1980s. We checked 26 combinations of these individual instruments to find the one that produces best results in terms of the instrument strength in the first stage and identification. As a result, we use percent of county area over shale play, a measure of recoverable tight oil and a measure of drilling intensity in the 1980s and time interactions of these three instruments as our instrument set for sensitivity analysis. Appendix C shows a map of U.S. major shale plays and describes instrument derivation in greater detail.

[8] This distinction follows Allcott and Keniston (2014), whereas distance adjustment elasticity of 0.8 (that corresponds to the 500-mile radius) as a cut-off value is based on Holmes and Stevens (2014).

Counties bordering shale development counties may benefit without directly participating in any drilling activity through commuting and other spillover mechanisms. Some studies remove these border counties from the analysis in order to ensure that they do not bias results (Black et al., 2005; Weber, 2012) whereas others directly control for spatial spillovers. Weinstein (2014) found evidence of spatial spillovers even though border counties did not have a statistically significant impact on the estimation of shale impacts within the drilling counties. We follow the latter approach and include a measure of energy performance in the border counties, $\Delta WEnGr_c = WEnGr_{jct} - WEnGr_{jct-3}$, to estimate spatial spillovers. The calculation of this variable follows closely that of $\Delta EnGr$. For each outcome *j* (energy earnings or energy employment) we derive totals for all bordering (contiguous) counties and calculate their 3-year growth rate using own county total earnings or total employment as the base ensuring that the coefficients on the measures of energy growth in own and surrounding counties are comparable. A first difference of the 3-year border-county growth rates is included in the model.

Although the differencing of the dependent and main explanatory variables should factor out all county-specific unchanging characteristics, the effects of the boom may have a "critical mass" effect when certain level of growth or accumulated volume in the energy sector is needed for the impacts to start snowballing and to disproportionally affect earnings and employment. To account for such a possibility, we include a measure of an energy boom in our empirical specification. It allows us to assess whether the spillovers that influence local earnings are stronger during a boom when the shock is large enough that it may transform local supply chains and increase agglomeration, attract migrants, and affect overall economic performance. To determine the boom period for each state we first use oil and gas production and oil and gas employment data provided by the U.S. EIA and BLS, respectively (the graphs and table of approximate beginning of the boom are reproduced from Weinstein (2014) and provided in Appendix B[9]). We then determine if the calculation of the differenced variables in Equation (1) involve any year that is defined as a boom year for a corresponding state or any year after it (when the boom is assumed to be present). If it is true, a dummy variable *Boom* is assigned the value of 1 and 0 otherwise. The coefficient β_3 shows the average shift for a boom period.

The last explanatory variable, $\Delta IndMix_c = IndMix_{jct} - IndMix_{jct-3}$, is an industry mix-type measure from shift-share analysis (sometimes called Bartik's instrument (Bartik, 1991)) that accounts for demand shocks stemming from industries nationally. The measure predicts total earnings (or employment) growth assuming that each industry within a county grows at the corresponding national

[9] We checked if the results were sensitive to slight variation in the selection of the boom years by running analysis using alternative assignment of boom years and the results did not generally differ from the reported ones.

rate of industry growth.[10] Equation 2 shows the formula for the undifferenced industry mix term.

$$IndMix_{jct} -= \sum_{s=1}^{N} S_{jsct-3} NatGr_{jst-3,t} \quad (2)$$

where all subscripts are identical to the above with subscript *s* indicating industry at the 4-digit NAICS level (NAICS2111 and NAICS2131 are excluded). By including the industry mix (Bartik) measure, we not only account for demand shocks that might be correlated with energy shocks, but the resulting regression coefficient is the multiplier effect on earnings (or employment) from an *average-sized* shock in the economy net of the oil and gas sector and is directly comparable in magnitude to the effects from county energy sector expansion and energy-related spillovers from neighboring counties.

The models also include a set of controls to factor out the influence of a number of economic and social characteristics that were found to be important for local economic performance in the previous literature. The legacy of mining may indicate a presence of infrastructure that makes oil and gas expansion easier and more favorable attitudes to the sector since it is something local residents may be accustomed to and comfortable with. Models estimated below include *Mining2001* measured by the employment share in all mining industries (NAICS21) in 2001. An industrial structure of a county is accounted by the 2001 shares of manufacturing and agricultural employment (*Manuf2001* and *Agri2001* respectively). The diversity of the local industrial composition that is likely to hedge against negative economic shocks and to stimulate growth is approximated by the inverse of the Herfindahl-Hirschman index (*Diversity2001*).[11] All variables described so far are calculated using the EMSI data set unless indicated otherwise. Three variables approximate the level of human capital in a community. *LessHS2000*, *BA2000* and *GradProf2000* are the 2000 shares of adult population with less than school diploma, with bachelor's degree but not professional or graduate degree, and with professional or graduate degree respectively. Finally, the effects of agglomeration on local performance are controlled for by the log of 2001 county population. The data for the latter four variables are derived from the U.S. Census Bureau. A dummy variable indicating time period accounts for national trends that uniformly affect all counties. Appendix Table 1D provides summary statistics for all variables.

4. Estimation results

[10] The "Bartik" instrument has become a standard first-stage instrument for employment growth given its growth is based on national growth rates. In our case, we want to account for the demand shocks that are likely to affect local performance differentially depending on local industrial composition.

[11] $Diversity2001_{ct}$=(10,000-$\sum_{s-1}^{N} S_{sct}^2$) where S_{sc}^2 is the square of industry *s* percentage share in total employment of county *c* in year *t.*

This section presents the main estimation results for all three measures of local economic performance, total earnings, average earnings (earnings per worker or EPW) and employment. Earnings and employment models use the main explanatory variables (energy growth, spillovers and the industry mix term) that correspond to the outcome of interest, i.e. for the models of total and average earnings, energy sector growth and energy sector spillovers are measured using *earnings* in the energy sector and the industry mix term is calculated using total earnings. The employment models calculate the three explanatory variables in an identical way but use employment instead of earnings. By comparing the employment and earnings multipliers, we can assess how much energy-sector job growth is associated with leakages of earnings or with increasing average wages—i.e., given that the energy sector has higher average wages, if the employment multiplier exceeds the earnings multiplier, then some of the earnings are leaking out.

4.1. Aggregate earnings and employment outcomes

We start with the aggregate outcome models estimated separately for nonmetro and metro counties using OLS (Table 1). Growth in oil and gas sector boosts growth in earnings and employment of the affected communities. On average after three years, each additional dollar earned in NAICS2111 and NAICS2131 adds $0.30 in earnings in other industries in nonmetro counties and $0.10 in earnings in other industries in metro counties. Likewise, each new job in the oil and gas industry creates 0.5 extra jobs in the rest of the local nonmetro economy with no evidence of spillovers into other industries in the metropolitan sample. Counties surrounded by oil- and gas-intensive areas appear to benefit from energy sector expansion with spatial spillovers observable for both earnings and employment. Metro counties tend to benefit sizably more from adjacent oil and gas extraction compared to nonmetro areas, consistent with more integrated local labor markets. Nearby rural oil and gas workers may wish to reside in urban counties, which can more easily provide goods and services for the oil and gas industry and their workers. The accumulation of energy effects is evident only for earnings, with *Boom* being statistically significant (although only marginally in one case) in all earnings models. Counties in the states affected by oil and gas booms enjoy higher total earnings growth and higher EPW growth on average. The combined effects of own and neighboring oil and gas drilling, although detectable in all county types and for all outcomes, are usually comparable to (and in some cases are smaller then) equally sized shocks from the rest of the economy as suggested by the significant positive coefficient on industry mix term. Thus, oil and gas multipliers turn out to differ little from the estimated multipliers for equal-sized shocks in the rest of the economy, suggesting that oil and gas is not a special industry case.

It also appears that oil and gas earnings multipliers are relatively modest and similar to oil and gas employment multipliers, suggesting relatively little of the earnings stay local given the common use of commuters in the oil and gas industry (Kinnaman, 2011; Munasib and Rickman, 2015).

Table 1. OLS estimation results for aggregate outcomes

Explanatory variable	ΔTotal earnings growth		ΔEarnings per worker growth		ΔEmployment growth	
	Nonmetro	Metro	Nonmetro	Metro	Nonmetro	Metro
ΔEnVar	1.3***	1.1***	.53***	.65***	1.5***	1***
	(0.11)	(0.14)	(0.06)	(0.11)	(0.17)	(0.17)
ΔWEnVar	8.2e-03***	.019**	5.0e-03***	.019*	4.6e-03***	.011**
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)
Boom	1.1***	.57*	.69***	.42***	.37	.12
	(0.34)	(0.34)	(0.16)	(0.16)	(0.23)	(0.26)
ΔIndMix	1.4***	1.4***	.45***	.54***	1.5***	1.4***
	(0.09)	(0.11)	(0.07)	(0.06)	(0.09)	(0.13)
Mining2001	-.028**	.012	-.016***	-1.7e-03	-.024**	6.4e-03
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Observations	6,018	3,165	6,018	3,165	6,018	3,165
R^2	0.320	0.471	0.143	0.189	0.358	0.524

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; standard errors clustered at BEA area level in parentheses; all models include a full set of controls as described in Section 3 (*Agri2001, Manuf2001, Diversity2001, LessHS2000, BA2000, GradProf2000, LgPop2001* and time period dummies).

4.2. Earning and employment outcomes across space

There may be significant differences in the multiplier effect across space especially with shale development occurring in areas without a recent history of oil and gas drilling (like Pennsylvania) and in areas with a long history of oil and gas drilling (as in Texas). North Dakota is one example of a remarkable boom in terms of both earnings and employment growth rates (Appendix Table1A) and it particularly stands out due to being very sparsely populated and remote, meaning that almost by definition, the necessary workforce had to in-migrate, which increases multipliers. The remoteness of the Bakken counties makes it less likely that workers in the oil and gas industry can travel long distances to in-commute or spend their earnings. Without an established oil and gas supply chain and infrastructure in close proximity, Bakken counties needed to quickly adjust in order to accommodate the industry (increasing the multiplier). Conversely, in the Oil Patch counties, with their established oil and gas supply chain and infrastructure, new shale development may be better accommodated resulting in a smaller multiplier.

We therefore examine the multiplier across regions by breaking our data into regions based on the six most significant shale plays (see Appendix C). For this analysis, we assign counties into one of four regions by state (plus a separate group for counties that do not enter any of the four groups of states with oil and gas development). These regions are: Rocky Mountain Bakken (North Dakota, South Dakota, Montana, Idaho and Minnesota); Rocky Mountain Niobrara (Colorado, Utah, Wyoming, Kansas and Nebraska); Mideast Marcellus (New York, Pennsylvania, Ohio, West Virginia, Delaware, Maryland, New Jersey, Kentucky, Virginia) and Southwest Oil (Texas, Oklahoma, Louisiana, Arkansas, Mississippi, New Mexico and Arizona). Table 2 shows the OLS estimation results by region.

Table 2. OLS estimation results for aggregate outcomes by regions

Explanatory variable	**ΔTotal earnings growth**		**ΔEarnings per worker growth**		**ΔEmployment growth**	
	Nonmetro	**Metro**	**Nonmetro**	**Metro**	**Nonmetro**	**Metro**
Rocky Mountain Bakken (ND, SD, MT, ID, MN)						
ΔEnVar	1.5***	-7.1***	.25**	-2.6	2.1***	-3.3*
	(0.26)	(2.11)	(0.11)	(2.36)	(0.21)	(1.83)
ΔWEnVar	.029***	.22***	4.5e-03	.17*	.045***	.1*
	(0.01)	(0.07)	(0.00)	(0.10)	(0.01)	(0.06)
Boom	.58	3***	.25	.73	.51	1.5***
	(0.59)	(0.99)	(0.32)	(0.73)	(0.53)	(0.48)
ΔIndMix	1.6***	1.5***	.36*	.45***	2***	2***
	(0.22)	(0.38)	(0.18)	(0.15)	(0.29)	(0.53)
Mining2001	-.077	.12*	-.037	.012	-.055	.15***
	(0.05)	(0.07)	(0.02)	(0.06)	(0.04)	(0.04)
Observations	771	144	771	144	771	144
R2	0.402	0.579	0.072	0.129	0.405	0.698
Rocky Mountain Niobrara (CO, UT, WY, KS, NE)						
ΔEnVar	1.5***	3.1*	.74***	1.7*	1.4***	2.6**
	(0.13)	(1.49)	(0.08)	(0.84)	(0.22)	(1.08)
ΔWEnVar	.025***	-.067**	.019**	-.026**	.012*	-.24
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.14)
Boom	.24	.46	.75	.72	-.23	-.042
	(0.81)	(0.92)	(0.46)	(0.44)	(0.49)	(0.87)
ΔIndMix	2.2***	1.6***	.86***	.8**	2***	1.4**
	(0.34)	(0.43)	(0.23)	(0.29)	(0.33)	(0.47)
Mining2001	1.5***	3.1*	.74***	1.7*	1.4***	2.6**
	(0.13)	(1.49)	(0.08)	(0.84)	(0.22)	(1.08)
Observations	777	162	777	162	777	162
R2	0.381	0.564	0.257	0.375	0.339	0.578
Mideast Marcellus (NY, PA, OH, WV, DE, MD, NJ, KY, VA)						
ΔEnVar	.75***	.9***	.66***	.69***	.81**	1***
	(0.26)	(0.18)	(0.11)	(0.16)	(0.32)	(0.30)
ΔWEnVar	.11	.16***	.066	.13***	.065	-.042

	(0.07)	(0.02)	(0.04)	(0.02)	(0.08)	(0.03)
Boom	2.3*	.54	1.1**	.28	.86	.18
	(1.21)	(0.57)	(0.55)	(0.33)	(0.66)	(0.41)
ΔIndMix	1.4***	1.1***	.5***	.53***	1.5***	1.1***
	(0.15)	(0.24)	(0.10)	(0.13)	(0.13)	(0.22)
Mining2001	-.065**	.054*	-.031*	-6.0e-03	-.045***	.072**
	(0.02)	(0.03)	(0.02)	(0.01)	(0.02)	(0.03)
Observations	837	765	837	765	837	765
R2	0.302	0.328	0.148	0.098	0.425	0.557
Southwest Oil (TX, OK, LA, AR, MS, NM, AZ)						
ΔEnVar	1.1***	1.1***	.56***	.55***	1.2***	1.1***
	(0.07)	(0.12)	(0.05)	(0.07)	(0.10)	(0.18)
ΔWEnVar	5.9e-03***	.017**	4.3e-03***	.016	3.4e-03***	.015*
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)
Boom	.27	1.8	-.37	.86	.8	.95
	(0.84)	(1.52)	(0.60)	(0.55)	(0.65)	(1.00)
ΔIndMix	1.4***	1.4***	.63***	.66***	1.4***	1***
	(0.21)	(0.26)	(0.14)	(0.15)	(0.26)	(0.31)
Mining2001	-.017	-.041	-.025*	-.032*	-9.6e-03	-.025
	(0.02)	(0.04)	(0.01)	(0.02)	(0.02)	(0.04)
Observations	1,275	519	1275	519	1,275	519
R2	0.304	0.615	0.283	0.431	0.301	0.423

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; standard errors clustered at the BEA area level in parentheses; all models include a full set of controls as described in Section 3 (*Mining2001, Agri2001, Manuf2001, Diversity2001, LessHS2000, BA2000, GradProf2000, LgPop2001* and time period dummies).

Table 2 shows wide variation in the effects of energy sector growth on earnings and employment both across regions and between nonmetro and metro counties. Overall, the results are somewhat consistent with prior expectations with the largest multipliers found in the Rocky Mountains region, very modest multipliers in the Oil Patch states and some crowding out in an average Marcellus county. This implies that the need to develop supportive infrastructure for the oil and gas development contributes to the increased local economic responses, further suggesting that once infrastructure is in place its positive effects are likely to subside and, if it is mostly industry-specific and cannot be used to support other industries in the energy bust period, may become a drag on local economies.

In the Bakken nonmetro counties, energy earnings and employment growth has 0.5 and 1.1 multiplier effect on total earnings and total employment respectively. Positive cross-county spillovers are detectable for total earnings and employment. A surprising finding for this region is that the explosive growth in the oil and gas industry seems to crowd out both total earnings[12] and total

[12] Crowding out is present in both tradable and non-tradable sectors according to the estimation results reported in Appendix F.

employment in the metropolitan counties. The results for metro counties, however, should be taken with considerable caution given the small number of observations in this subsample. Large positive multipliers are observed in the Rocky Mountain Niobrara region (including metro counties although in some models the results are only weakly significant). In this group, drilling activity in the adjacent counties tends to stimulate earnings and employment in nonmetro counties and suppress earnings growth in metropolitan areas, although the small number of observations in this metro group may also mean the results are less reliable. The boom variable is statistically unimportant while a recent legacy of mining seems to boost economic performance in terms of earnings and employment in all types of counties.

The Marcellus region is an outlier. Here, energy sector growth has crowding out effects for both total earnings and employment with positive and relatively large earnings spillovers into metro counties. Being part of a booming area somewhat helps earnings growth in the nonmetro sample while a legacy of mining hinders nonmetro economic growth and helps metro growth in total earnings and employment. States more traditionally engaged in the oil and gas extraction (Southwest Oil region) enjoy very modest positive effects of the energy sector most likely due to the presence of infrastructure and qualified labor. Positive spatial spillovers are detectable in all models; although they are relatively small in the nonmetro sample and generally do not differ from the aggregate estimates reported in Table 1. The boom variable is insignificant, potentially due to a relatively modest increase in oil and gas production compared to the baseline production volumes in this region.

The analysis by region further confirms that the demand shock resulting from the rapid expansion of the oil and gas industry is modest compared to the shocks from the rest of the economy. In the majority of the models reported in Table 2, the industry mix coefficients are larger than that on energy growth. Given the pronounced cycle-like development of the energy sector, the benefits from the recent boom are likely to disappear as the cycle goes into a bust, leaving many communities suffering economically, especially in remote and rural areas that lack alternative engines of growth. Our analysis suggests that overreliance on the oil and gas industry in economic development might be detrimental to future growth prospects. A more holistic approach that targets a multitude of industries appears to be more likely to yield sustainable positive results.

4.3. Earnings and employment outcomes across sectors

The aggregate results reported in Table 1 could be obscuring heterogeneous effects across industries. Specifically, we focus on the impact on tradable goods (Table 3) versus non-tradable goods (Table 4) to examine whether any crowding out or the Dutch Disease-like effects are occurring. To assess this, we use the dependent variables calculated separately for tradable and nontradable sectors as described in Section 3. The tradable and non-tradable counterparts of the total earnings and employment variables are scaled to total county earnings and employment, respectively, and are consistent with the scaling of the main explanatory variables. Thus, the ensuing coefficients can be interpreted as multipliers.

Table 3. OLS estimation results for the tradable sector

Explanatory variable	**ΔTradable earnings growth**		**ΔTradable EPW growth**		**ΔTradable employment growth**	
	Nonmetro	**Metro**	**Nonmetro**	**Metro**	**Nonmetro**	**Metro**
ΔEnVar	-.028	-.019	-.043	7.4e-04	-.013	-.061
	(0.03)	(0.02)	(0.08)	(0.14)	(0.04)	(0.05)
ΔWEnVar	2.1e-03***	2.8e-03**	-6.9e-04	.014	5.2e-03***	5.3e-03
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
Boom	8.5e-03	-.18	1.3***	-.062	-.068	-.11
	(0.12)	(0.14)	(0.49)	(0.56)	(0.11)	(0.09)
ΔIndMix	.52***	.45***	.56***	.68***	.59***	.42***
	(0.04)	(0.07)	(0.17)	(0.14)	(0.05)	(0.06)
Mining2001	-.019***	-8.3e-03	-.072***	-.11***	-1.8e-03	.017***
	(0.01)	(0.01)	(0.02)	(0.03)	(0.01)	(0.01)
Observations	6,018	3,165	6,018	3,165	6,018	3,165
R^2	0.128	0.228	0.006	0.020	0.144	0.221

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; standard errors clustered at BEA area level in parentheses; all models include a full set of controls as described in Section 3 (*Agri2001, Manuf2001, Diversity2001, LessHS2000, BA2000, GradProf2000, LgPop2001* and time period dummies).

Overall, Table 3 shows no statistical indication of Dutch Disease as measured by total earnings, EPW and employment growth in tradable industries, but there are no signs of positive spillovers as well. Although most of the coefficients on the energy growth variable are negative, they are statistically insignificant. One reason might be that a timespan longer than three years (the differencing used in this research) is required for the negative relationship between energy sector expansion and performance in the tradable sector to be uncovered. Another explanation is heterogeneity across space that may be concealed in analyzing the whole country. Separate analyses by four regions (Appendix Table 1F) show that for total earnings, crowding out in the nonmetro sample is detected in the Rocky Mountain

Niobrara and Southwest Oil regions and in the metro sample in the Rocky Mountain Bakken region whereas positive effects are observed in the metro counties of the Mideast Marcellus region.

The next section returns to this issue presenting IV estimates for tradable and nontradable industries. To preview the IV results, there is evidence of crowding out in the total tradable earnings in nonmetro counties. Since this specific model shows endogeneity as suggested by the Durbin P-value, the IV results are preferred. We, therefore, conclude that there is evidence of the Dutch Disease phenomenon in the US continental nonmetro counties, at least in certain regions of the country. Mostly negative effect of a longer legacy of mining on earning outcomes may be interpreted as lending additional (although indirect) support for this conclusion. Drilling activity in neighboring counties tends to boost total earnings in metro and nonmetro counties, as well as nonmetro employment. Conversely, average shocks in the rest of the economy have consistently positive effects on the non-tradable sector across all county types.

Table 4. OLS estimation results for the non-tradable sector

Explanatory variable	**ΔNon-tradable earnings growth**		**ΔNon-tradable EPW growth**		**ΔNon-tradable employment growth**	
	Nonmetro	**Metro**	**Nonmetro**	**Metro**	**Nonmetro**	**Metro**
ΔEnVar	.35***	.15	.15**	.068	.51***	.076
	(0.10)	(0.15)	(0.06)	(0.17)	(0.14)	(0.17)
ΔWEnVar	6.1e-03***	.017**	6.6e-03***	.022**	-6.8e-04	5.9e-03
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)
Boom	1.1***	.75***	.72***	.53***	.44**	.23
	(0.31)	(0.28)	(0.17)	(0.17)	(0.21)	(0.22)
ΔIndMix	.93***	.93***	.41***	.42***	.94***	1***
	(0.10)	(0.10)	(0.06)	(0.06)	(0.08)	(0.12)
Mining2001	-9.2e-03	.021*	-.012**	6.4e-03	-.022**	-.011
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Observations	6,018	3,165	6,018	3,165	6,018	3,165
R^2	0.144	0.349	0.064	0.103	0.219	0.448

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; standard errors clustered at BEA area level in parentheses; all models include a full set of controls as described in Section 3 (*Agri2001, Manuf2001, Diversity2001, LessHS2000, BA2000, GradProf2000, LgPop2001* and time period dummies).

As follows from Table 4, recent developments in the oil and gas industry have benefited the non-tradable sector in affected nonmetro counties by raising earnings and employment with additional positive spillovers from neighboring counties (the analysis by region in Table 2F shows that this effects is strong in all regions except for the Mideast Marcellus). The energy boom overall has predominantly strong positive effects on the non-tradable sector with stronger stimulating effects in the nonmetro sample. In line with earlier findings, however, positive effects from energy growth tend to be smaller than equal-sized exogenous shocks in the rest of the economy.

5. Additional and sensitivity analyses

Our econometric specification removes county fixed effects that capture unobserved time-invariant factors that may affect both oil and gas development and earnings or employment growth. For example, county fixed effects control for whether shale boom counties have a particularly favorable pro-business tax environment that may affect current earnings (and job) growth assuming the strength of these effects does not change over time. We allow the effects to vary across boom and non-boom periods to account for additional heterogeneity. Moreover, our models control for other county features such as industry composition, education and agglomeration. These efforts should greatly mitigate any concerns for potential unobserved *time-varying* factors that affect earnings (and employment). Yet, a number of systematic factors such as oil prices and technology may influence a likelihood of a community to welcome extraction. Thus, we use an instrumental variable strategy to instrument for oil and gas earnings and employment. Table 5 reports estimation results for the aggregate outcomes.

Table 5. IV estimation results for aggregate outcomes

Explanatory variable	ΔTotal earnings growth		ΔEarnings per worker growth		ΔEmployment growth	
	Nonmetro	**Metro**	**Nonmetro**	**Metro**	**Nonmetro**	**Metro**
ΔEnVar	1.429***	1.727***	0.906***	1.280***	1.327***	0.0855
	(0.139)	(0.343)	(0.0783)	(0.201)	(0.188)	(0.654)
ΔWEnVar	0.0077***	0.0144***	0.0032***	0.0140***	0.0049***	0.0233*
	(0.00123)	(0.00475)	(0.000692)	(0.00278)	(0.00100)	(0.0123)
Boom	1.051**	0.460	0.550*	0.307	0.399	0.181
	(0.502)	(0.465)	(0.282)	(0.272)	(0.299)	(0.307)
ΔIndMix	1.445***	1.368***	0.435***	0.526***	1.525***	1.453***
	(0.0621)	(0.0667)	(0.0349)	(0.0391)	(0.0576)	(0.0748)
Mining2001	-0.0270	0.0159	-0.0127	0.00198	-0.0241	0.00364
	(0.0200)	(0.0202)	(0.0113)	(0.0118)	(0.0154)	(0.0184)
IV F stat (1st stage)	69.68	23.33	69.68	23.33	69.55	25.51
Durbin P-value	0.419	0.070	0.000	0.001	0.333	0.139
Overid test P-value	0.000	0.000	0.002	0.089	0.000	0.000
Observations	6,018	3,165	6,018	3,165	6,018	3,165

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; standard errors in parentheses; all models include a full set of controls as described in Section 3 (*Mining2001, Agri2001, Manuf2001, Diversity2001, LessHS2000, BA2000, GradProf2000, LgPop2001* and time period dummies).

The diagnostic tests results reported in the lower rows of Table 5 show that the instrument set used for estimation is strong (the first stage F-statistics is greater than 23 in all cases) but only earnings per worker models show evidence of endogeneity (Durbin p-value). The results, however, are rather consistent with OLS estimates previously reported except for the total metro earnings growth. Again, the coefficients on the main continuous explanatory variables in the total earnings and employment growth models are multipliers, which means that after 3 years, for example, each additional dollar earned in NAICS2111 and NAICS2131 leads to extra $0.43 earned in other nonmetro industries locally (compared to $0.3 in the OLS results); likewise, each additional job in the oil and gas industry creates about 0.3 new jobs elsewhere in the nonmetro local economy (compared to 0.5 jobs estimated by OLS). In the average earnings growth models, IV estimates are larger than that of OLS, indicating a stimulating effect of energy development on EPW after three years. Yet, they do not indicate any fundamental transformation relative to growth in the rest of the local economy.

Although these results should be taken with caution, Table 5 shows distinctive impacts for oil and gas development on earnings and employment. Whereas newly created jobs in energy affect total employment via spillovers to other local industries in only nonmetro counties, both nonmetro and metro counties benefit from energy sector expansion in terms of earnings. It appears that metropolitan counties tend to enjoy larger growth in total and average earnings as a result of additional earnings in the oil and gas industry compared to their nonmetro counterparts. This could relate to the fact that higher-paying energy company headquarters as well as industry support activities tend to disproportionately locate in urban areas. Counties also benefit from energy sector expansion via spillovers from their neighbors. Growth in the oil and gas industry in nearby counties creates positive spillovers with these effects being at least twice as large in the metro sample.

The magnitude of the impacts from energy earnings growth on total county earnings is largely comparable to the effects of the demand shock (industry mix term) from all other industries except for EPW. The energy boom appears to play an additional (beyond the direct effects of oil and gas industry growth) role in boosting county economic performance only in the nonmetro subsample and only for earnings, in which the effects on earnings per worker are weakly significant. The legacy of mining does not play a role in promoting economic performance of localities a decade later, most likely because any effects do not change over time and are factored out by the differencing strategy.

In the sectoral analysis, several models might suffer from endogeneity of the estimated relationship as follows from the endogeneity test results reported under Durbin P-val heading in two tables below. Thus, we report IV results for tradable and non-tradable industries in Tables 6 and 7, respectively. As previewed in the previous section, the most important finding from Table 6 is that the IV estimation is likely to give more reliable estimates for the total earnings model in the nonmetro sample. According to Table 6, energy earnings growth has a suppressing effect on total tradable earnings growth consistent with the Dutch Disease hypothesis. Results for the non-tradable sector in Table 6 are provided for completeness. They are in general consistent with the OLS results showing stimulating role of energy sector expansion in local economic performance. Unlike the OLS results, however, the positive effects are observable in the metro sample for the earnings outcomes.

Table 6. IV estimation results for the tradable sector

Explanatory variable	ΔTradable earnings growth		ΔTradable EPW growth		ΔTradable employment growth	
	Nonmetro	**Metro**	**Nonmetro**	**Metro**	**Nonmetro**	**Metro**
ΔEnVar	-0.145**	0.105	0.0875	1.563**	-0.109	0.0614
	(0.0591)	(0.134)	(0.261)	(0.662)	(0.0964)	(0.246)
ΔWEnVar	0.0027***	0.0018	-0.0013	0.0007	0.0054***	0.0037
	(0.0005)	(0.0019)	(0.0023)	(0.0091)	(0.0005)	(0.0046)
Boom	0.0531	-0.203	1.267	-0.344	-0.0518	-0.116
	(0.213)	(0.181)	(0.939)	(0.896)	(0.153)	(0.115)
ΔIndMix	0.528***	0.451***	0.551***	0.638***	0.586***	0.415***
	(0.0263)	(0.0260)	(0.116)	(0.129)	(0.0295)	(0.0281)
Mining2001	-0.0197**	-0.0076	-0.0705*	-0.102***	-0.0019	0.0177**
	(0.0085)	(0.0079)	(0.0375)	(0.0389)	(0.0079)	(0.0069)
IV F stat (1st stage)	69.68	23.33	69.68	23.33	69.55	25.51
Durbin P-value	0.036	0.335	0.600	0.013	0.296	0.607
Overid test P-value	0.389	0.172	0.001	0.574	0.194	0.102
Observations	6,018	3,165	6,018	3,165	6,018	3,165

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; standard errors in parentheses; all models include a full set of controls as described in Section 3 (*Mining2001, Agri2001, Manuf2001, Diversity2001, LessHS2000, BA2000, GradProf2000, LgPop2001* and time period dummies).

Table 6. IV estimation results for the non-tradable sector

Explanatory variable	ΔNon-tradable earnings growth		ΔNon-tradable EPW growth		ΔNon-tradable employment growth	
	Nonmetro	**Metro**	**Nonmetro**	**Metro**	**Nonmetro**	**Metro**
ΔEnVar	0.575***	0.622*	0.605***	0.790***	0.436***	-0.976
	(0.124)	(0.318)	(0.0822)	(0.204)	(0.164)	(0.611)
ΔWEnVar	0.0050***	0.0126***	0.0044***	0.0156***	-0.00054	0.0196*
	(0.0011)	(0.0044)	(0.0007)	(0.0028)	(0.0009)	(0.0114)
Boom	0.998**	0.663	0.547*	0.400	0.451*	0.297
	(0.447)	(0.430)	(0.296)	(0.276)	(0.260)	(0.286)
ΔIndMix	0.917***	0.917***	0.389***	0.400***	0.938***	1.038***

	(0.0553)	(0.0617)	(0.0366)	(0.0396)	(0.0502)	(0.0698)
Mining2001	-0.0073	0.0235	-0.0078	0.0105	-0.0223*	-0.0141
	(0.0178)	(0.0187)	(0.0118)	(0.0120)	(0.0135)	(0.0171)
IV F stat (1st stage)	69.68	23.33	69.68	23.33	69.55	25.51
Durbin P-value	0.056	0.122	0.000	0.000	0.620	0.072
Overid test P-value	0.000	0.000	0.337	0.166	0.000	0.000
Observations	6,018	3,165	6,018	3,165	6,018	3,165

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; standard errors in parentheses; all models include a full set of controls as described in Section 3 (*Mining2001, Agri2001, Manuf2001, Diversity2001, LessHS2000, BA2000, GradProf2000, LgPop2001* and time period dummies).

Given a profound reliance of the oil and gas industry on commuters and in-migrant workers, especially in the areas that are newly undergoing rapid industry development, it is important to assess how much of the income generated by the energy sector expansion remains local. Theoretically, all positive coefficients estimated above could stem from the employment and earnings that go to people not residing in the impacted county (as EMSI earnings and employment data are based on place of work *not* place of residence). To assess this possibility for total earnings, we first re-run our OLS model with the dependent variable being the change in growth in (place-of-work) total earnings in all industries (except for oil and gas). We then use U.S. BEA data on *residential* earnings (including energy earnings) to estimate how much of the net earnings remain local. The results are shown in Table 7.

Table 7. OLS estimation results for alternative measures of total earnings

Explanatory variable	**ΔNon O&G earnings growth**		**ΔResidential earnings growth**	
	Nonmetro	**Metro**	**Nonmetro**	**Metro**
ΔEnVar	.32***	.13	1.1***	.87***
	(0.11)	(0.14)	(0.10)	(0.11)
ΔWEnVar	8.2e-03***	.019**	-1.1e-04	.013***
	(0.00)	(0.01)	(0.00)	(0.00)
Boom	1.1***	.57*	1.6***	1***
	(0.34)	(0.34)	(0.52)	(0.33)
ΔIndMix	1.4***	1.4***	.84***	1.3***
	(0.09)	(0.11)	(0.11)	(0.10)
Mining2001	-.028**	.012	-5.3e-04	4.0e-03
	(0.01)	(0.01)	(0.01)	(0.01)
Observations	6,018	3,165	6,018	3,165
R2	0.206	0.438	0.282	0.480

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; standard errors in parentheses; all models include a full set of controls as described in Section 3 (*Mining2001, Agri2001, Manuf2001, Diversity2001, LessHS2000, BA2000, GradProf2000, LgPop2001* and time period dummies).

The results for the non-oil and gas earnings are consistent with those reported in Table 1. Each added dollar earned in the oil and gas industries creates an extra $0.3 dollars earned elsewhere in the local economy. The energy coefficients for *residential* earnings growth are smaller. In nonmetro counties, each new dollar earned in the oil and gas sector adds only 10 cents of extra spillover earnings for *local residents* (i.e., 1.1 – 1.0 = 0.1). The place-of-work earnings multiplier of 1.3 (from col. 1, Table 1) suggests that the total impact of an added $1 of oil and gas earnings is $1.30 ($1 in direct oil and gas earnings and 30 cents in net earnings for other industries). Thus, we infer that $1.10 in net residential earnings remains in the county and 20 cents leaves due to commuting ($1.30 - $1.10).

Regarding metro residential earnings, column 4 suggests that each additional oil and gas earned dollar crowds out about 13 cents of residential earnings (1.0 – 0.87). Given that total place-of-work earnings in metro counties increase by $1.10 (multiplier of 1.1 in col. 2,Table 1), we infer that one dollar of new oil and gas earnings increases earnings of in-commuters by 23 (net) cents (1.1 – 0.87 = 0.23). Thus, the overall leakage in nonmetro counties equals 20% of the direct energy earnings and 23% in metro counties. This leakage limits the effects of energy booms to lift *residential* living standards. We conclude that at least for total earnings, the multipliers from energy sector expansion are modest, especially compared to energy-industry funded studies.

6. Conclusion

A number of studies have examined the economic impact of the latest U.S. energy boom, mostly focusing on job creation. We instead consider the impact of oil and gas development on earnings, tracing spatial and sectoral distribution of these effects, as well as their allocation between residents and nonresidents. Our findings suggest that the impact of recent U.S. energy boom on earnings is more modest than some industry-funded studies have predicted, though our employment multiplier estimates are generally consistent with previous academic studies. We find the (place-of-work) earnings multiplier is 1.3 for nonmetro counties and 1.1 for metro counties; every additional dollar earned in the oil and gas industry is associated with an increase of 30 and 10 cents in non-oil and gas sector earnings in nonmetro and metro counties, respectively. As a *share of direct energy earnings*, the increase in total *residential* earnings beyond the direct energy earnings only equals 10% in nonmetro counties and actually declines by 13% in the metro sample. These findings are unsurprising given the widespread use of in-migrant workers by the oil and gas industry. The evidence of a “leakage” of the oil and gas related earnings and employment is further reinforced by the positive spillovers from the nearby counties, which are at least twice as large for the metro counties, suggesting that energy workers may prefer to live in metro counties and commute to nonmetro counties where extraction mostly takes place.

We find that the earnings multiplier varies by region and across tradable and non-tradable sectors. As a result, the conclusions of studies that look at the aggregate outcomes for a country or for large regions should not be expected to apply to every county that considers oil and gas development. The effects are likely to be larger in the areas with rich resources and little existing infrastructure, which will need to be built in order to accommodate new energy sector demands. The factors that contribute to a higher expected positive impact of oil and gas development on local economic performance, however, are likely to simultaneously undermine future growth prospects of localities after the boom turns into a bust. For example, in-migrant workers will leave, while resource-rich communities will be left with industrial structure tailored to accommodate a declining industry. This dynamics can be observed in the experience of, for example, the Bakken region. After the energy boom of the 1970s and the subsequent bust in the 1980s, it suffered significant population losses that persisted for about two decades until the new boom took place. Several studies point that the localities that benefited from previous energy sector expansions tended to suffer larger (and quicker) decline after the boom period concluded (Jacobsen and Parker, 2014; Allcott and Keniston, 2014).

Our findings suggest that reliance on energy sector as the only lead of local economic growth is likely to have limited and temporal success. The positive spillovers from the oil and gas industry are usually smaller than the effects of the equal-sized shocks in the rest of the economy. Previous research shows that resource-rich regions may lack incentives for diversification of their economies and tend to underinvest in other productive assets (Van der Ploeg, 2011). It is, therefore, crucially important for local policymakers to take a diversified economic development approach purposefully reinvesting additional resources generated by the oil and gas boom into building a healthy and balanced local industrial structure that would support sustained growth and wellbeing of residents in the long run.

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Appendix A

Table 1A. Energy* employment and total earnings** growth between 2001 and 2014 by state, %

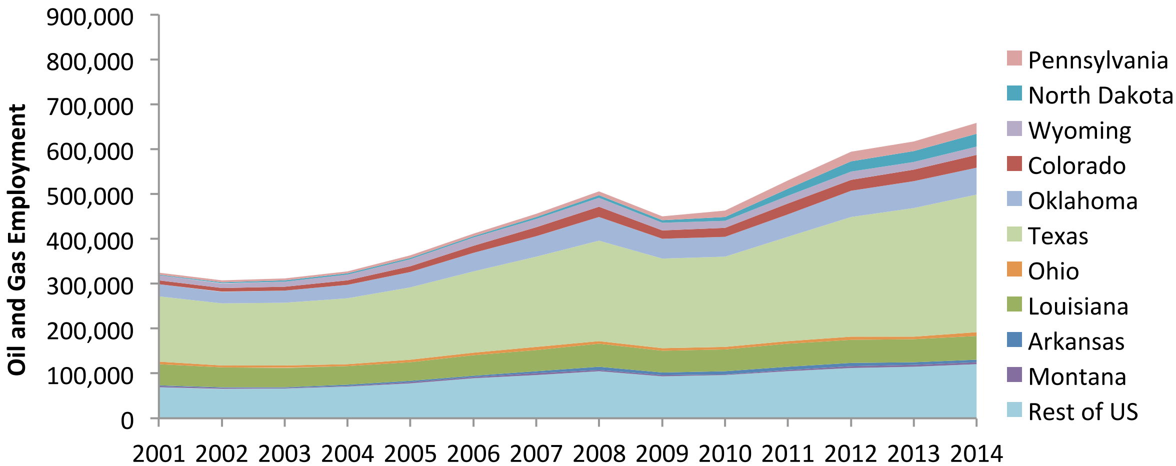
State	Employment	Earnings	State	Employment	Earnings
AL	25.88	37.89	NE	24.50	49.87
AZ	407.08	486.59	NV	164.33	243.70
AR	231.85	348.44	NH	25,772.73	36,909.53
CA	29.82	40.34	NJ	179.58	183.38
CO	271.19	268.60	NM	96.89	138.70
CT	-48.34	1,697.52	NY	65.05	96.36
DE	-83.18	-92.07	NC	-57.64	-64.38
FL	67.32	-15.32	ND	1,409.73	2,303.02
GA	79.42	124.75	OH	23.31	17.06
ID	478.55	662.96	OK	123.19	183.92
IL	60.04	96.34	OR	91.90	33.14
IN	211.09	266.31	PA	425.83	611.22
IA	176.17	40.64	RI	458.67	1,056.54
KS	65.06	79.08	SC	44.26	24.87
KY	130.64	157.51	SD	60.35	59.27
LA	10.44	32.37	TN	116.79	150.27
ME	-58.59	-25.21	TX	112.46	141.32
MD	249.01	80.69	UT	170.29	236.88
MA	1,166.05	1,009.15	VT	523.83	-13.52
MI	33.08	42.36	VA	26.36	39.43
MN	342.50	1,034.48	WA	-16.89	-36.25
MS	60.16	111.95	WV	113.46	195.33
MO	372.05	730.44	WI	278.65	218.19
MT	190.38	290.53	WY	86.43	153.12

Source: calculations from EMSI data

* NAICS2111 and NAICS2131 industries

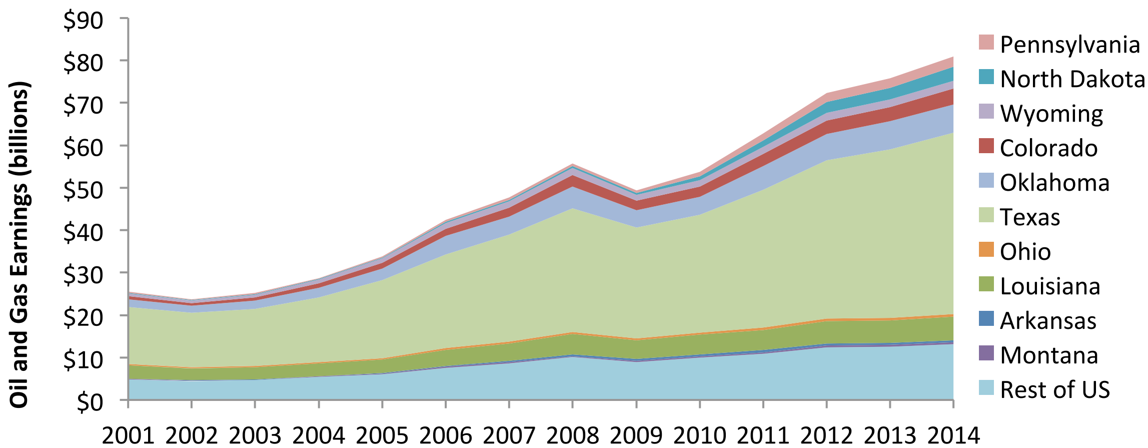
** total earnings are adjusted for inflation

Figure 1A. Total oil and gas employment by state



Source: EMSI employment data using NAICS codes 2111 and 2131

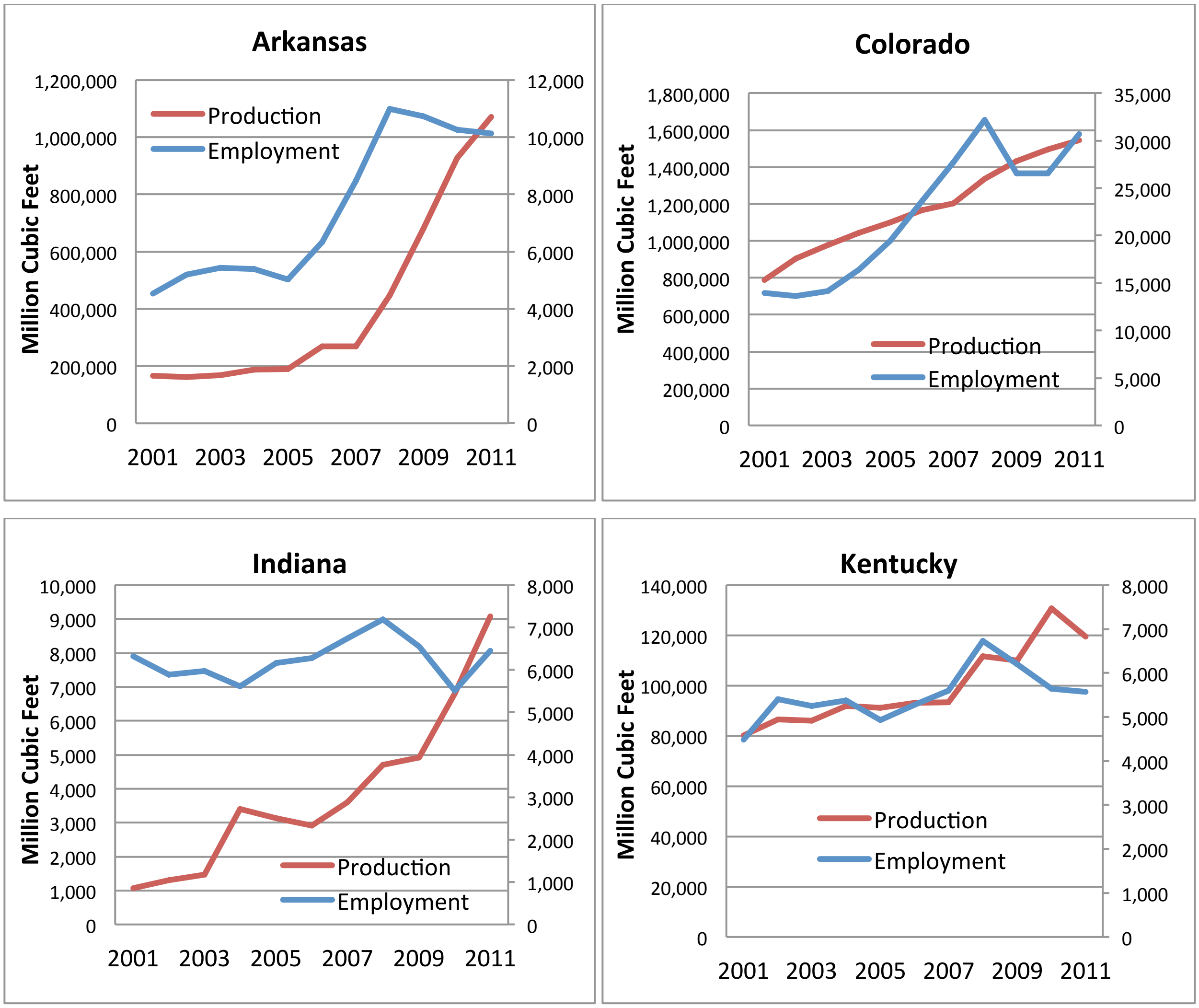
Figure 2A. Total oil and gas earnings by state

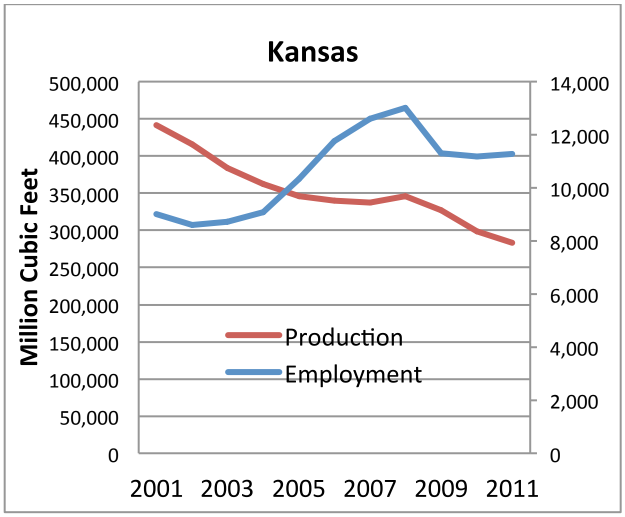


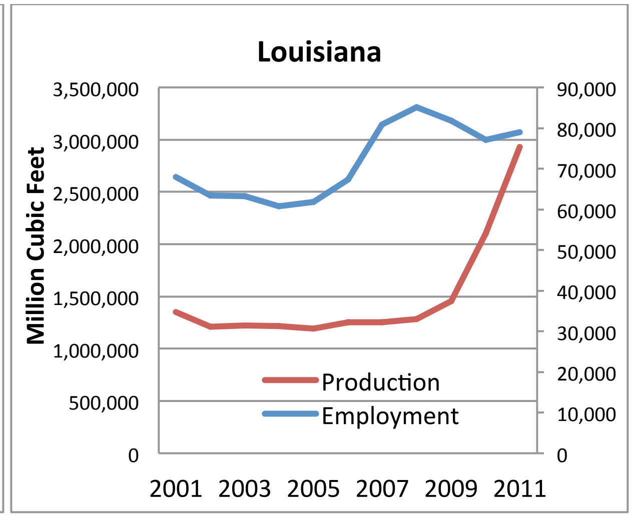
Source: EMSI earnings data using NAICS codes 2111 and 2131

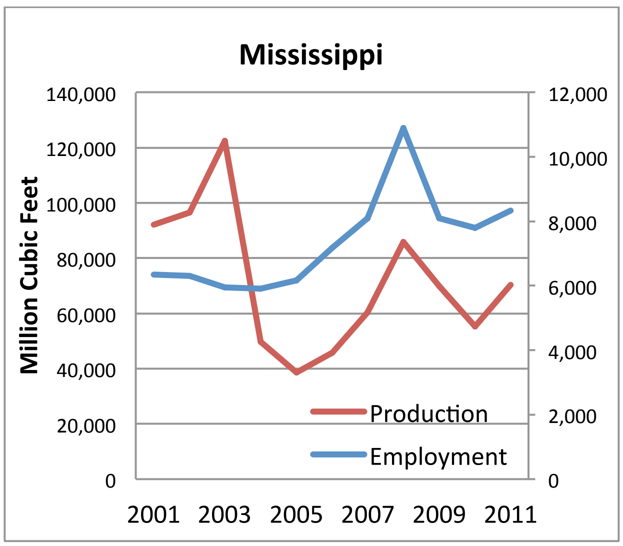
Appendix B

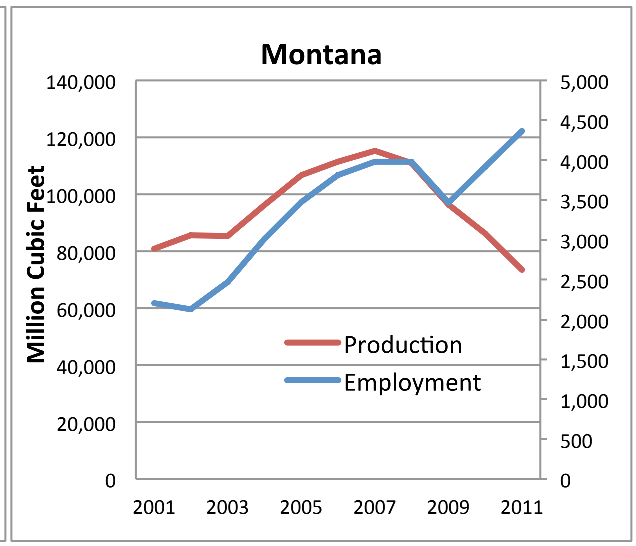
Figure 1B. Boom periods by state (oil and gas employment and production)

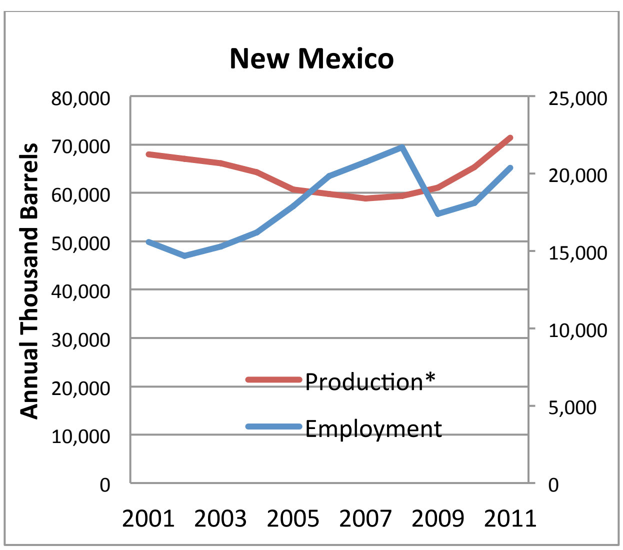


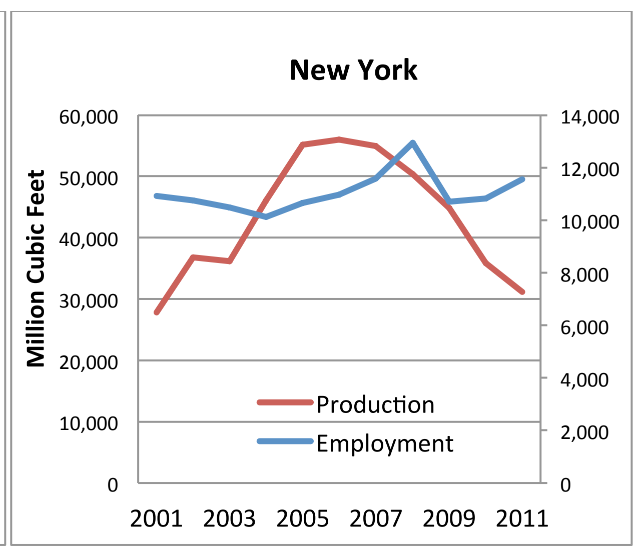

Kansas
Million Cubic Feet
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Production
Employment
2001
2003
2005
2007
2009
2011

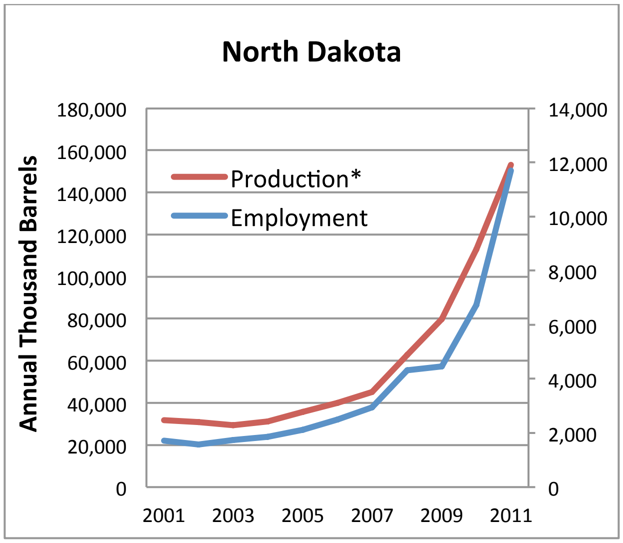

Louisiana
Million Cubic Feet
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Production
Employment
2001
2003
2005
2007
2009
2011

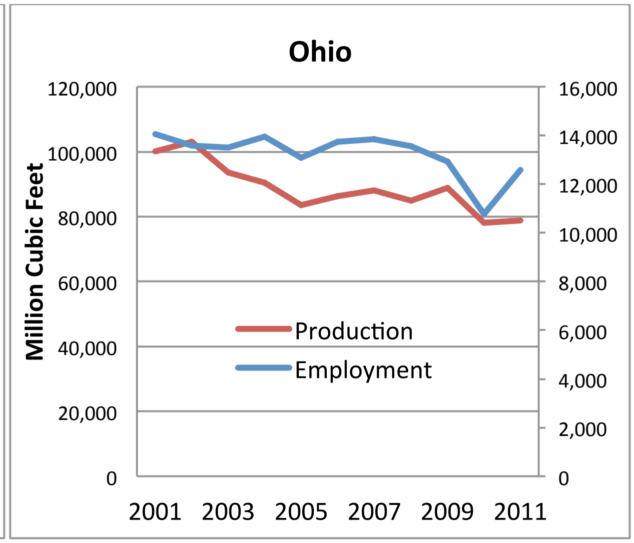

Mississippi
Million Cubic Feet
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
12,000
10,000
8,000
6,000
4,000
2,000
0
Production
Employment
2001
2003
2005
2007
2009
2011

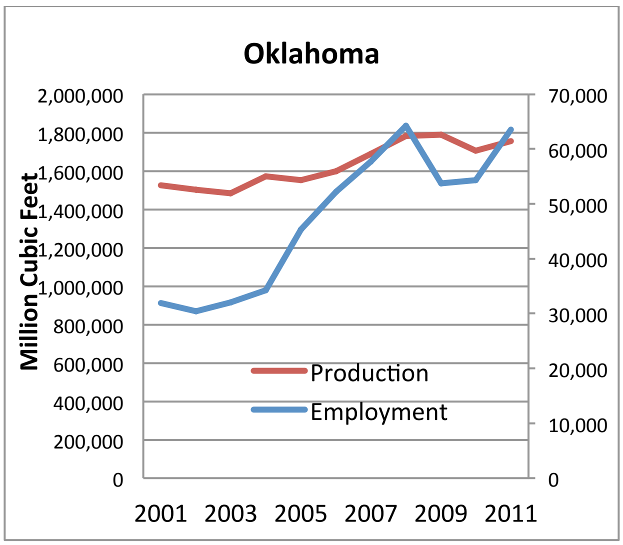

Montana
Million Cubic Feet
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Production
Employment
2001
2003
2005
2007
2009
2011

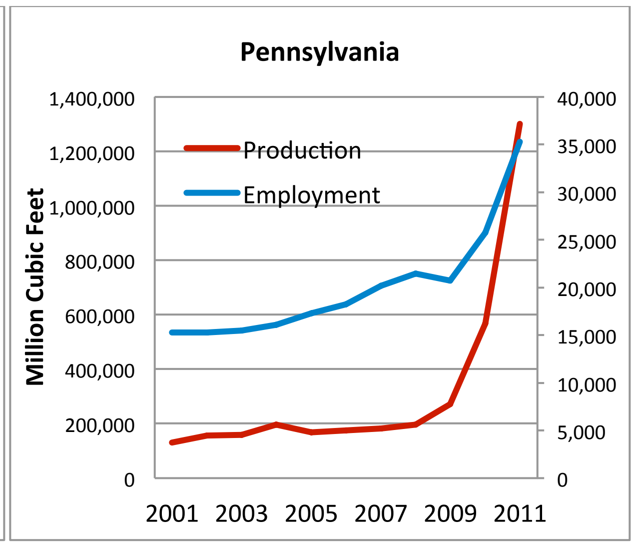

New Mexico
Annual Thousand Barrels
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
25,000
20,000
15,000
10,000
5,000
0
Production*
Employment
2001
2003
2005
2007
2009
2011

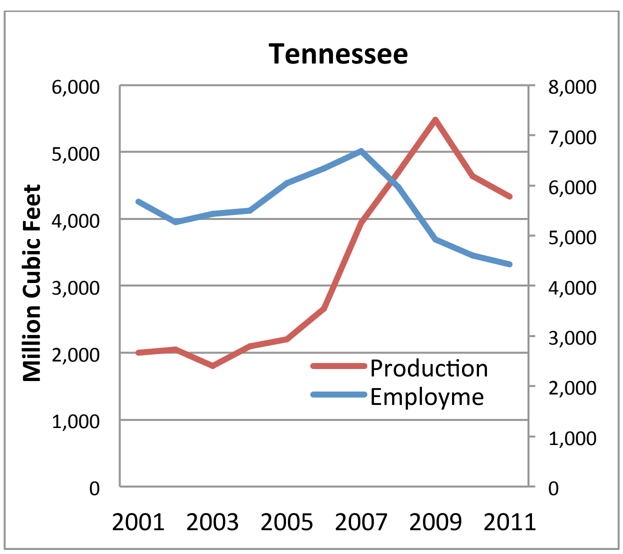

New York
Million Cubic Feet
60,000
50,000
40,000
30,000
20,000
10,000
0
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Production
Employment
2001
2003
2005
2007
2009
2011

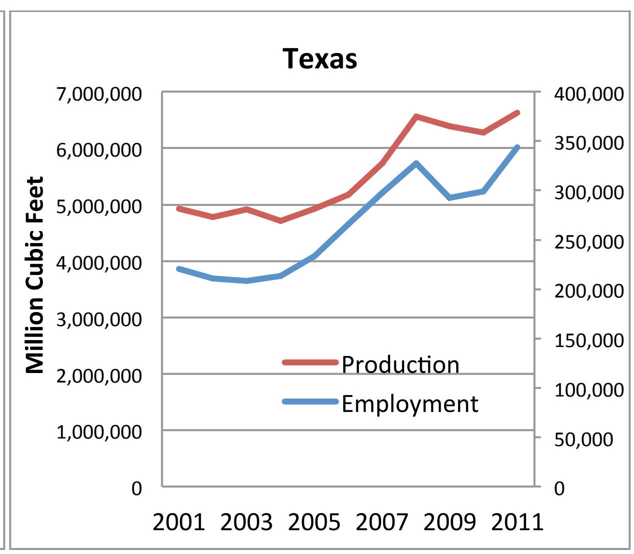

North Dakota
Annual Thousand Barrels
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Production*
Employment
2001
2003
2005
2007
2009
2011


Ohio
Million Cubic Feet
120,000
100,000
80,000
60,000
40,000
20,000
0
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Production
Employment
2001
2003
2005
2007
2009
2011


Oklahoma
Million Cubic Feet
2,000,000
1,800,000
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Production
Employment
2001
2003
2005
2007
2009
2011


Pennsylvania
Million Cubic Feet
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Production
Employment
2001
2003
2005
2007
2009
2011


Tennessee
Million Cubic Feet
6,000
5,000
4,000
3,000
2,000
1,000
0
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Production
Employme
2001
2003
2005
2007
2009
2011


Texas
Million Cubic Feet
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
400,000
350,000
300,000
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150,000
100,000
50,000
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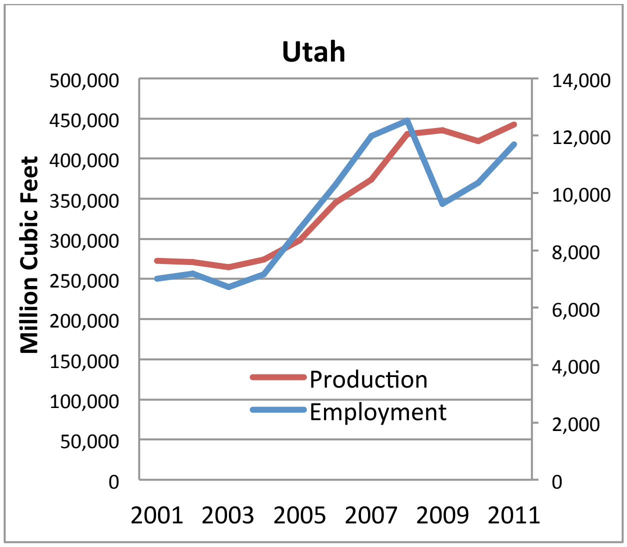
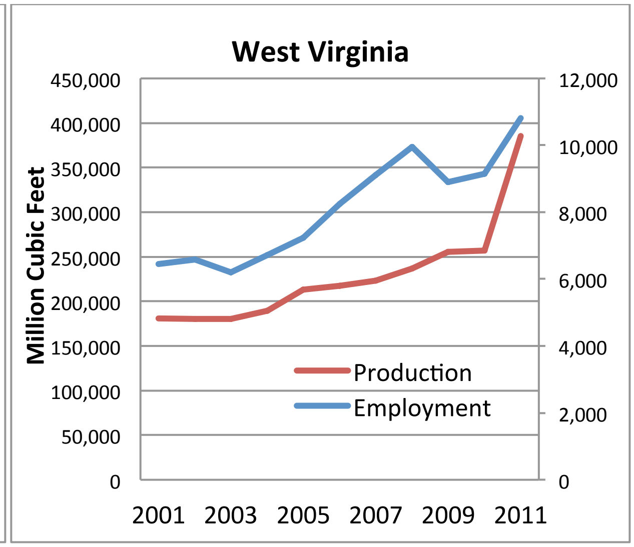
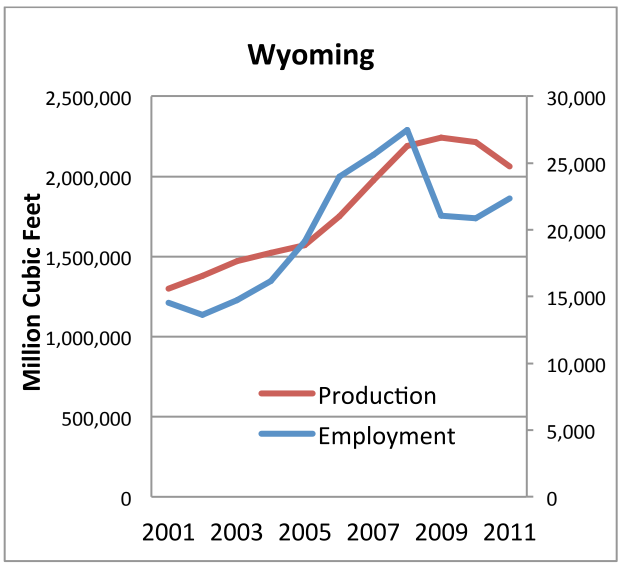
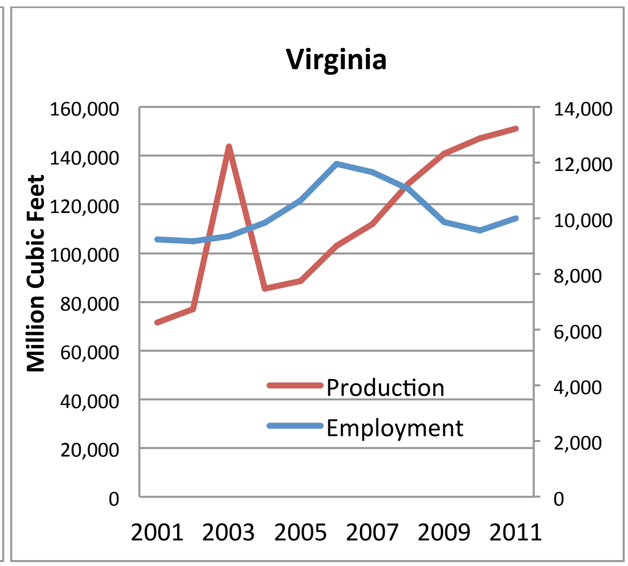
Production
Employment
2001
2003
2005
2007
2009
2011









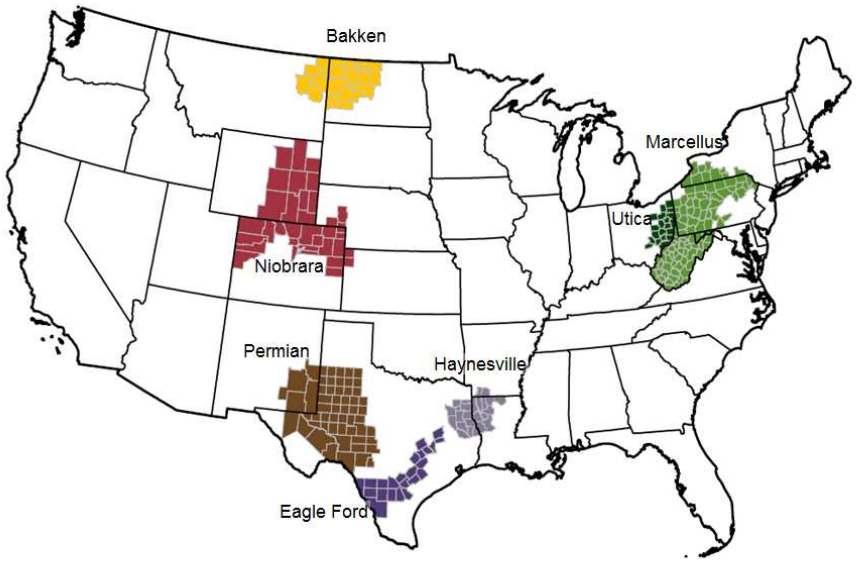
Source: U.S. BLS and EIA

Table 1B. Boom periods by state

State	Boom Period
Arkansas	2005
Colorado	2003
Indiana	2004
Kansas	2004
Kentucky	2005
Louisiana	2005
Mississippi	2005
Montana	2002
New Mexico	2004
New York	2004
North Dakota	2003
Ohio	2010
Oklahoma	2004
Pennsylvania	2006
Tennessee	2004
Texas	2004
Utah	2004
Virginia	2004
West Virginia	2003
Wyoming	2002

Appendix C

Figure 1C. Map of significant shale plays in the U.S.



Source: EIA http://www.eia.gov/petroleum/drilling/#tabs-summary-2

Instruments

Instruments used in this study are described below.

1. *Percent* is a percent of county's area that lies above a shale play;

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. *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 these instruments, the set of instruments used includes interaction of *Percent*, *Oil* and *Miles* with time periods in order to factor out time-varying endogeneity.

Appendix D

Table 1D. Summary statistics for the variables by sample

Variable	Nonmetro counties				Metro counties			
	Mean	**Std. Dev.**	**Min**	**Max**	**Mean**	**Std. Dev.**	**Min**	**Max**
Dependent variables								
ΔTotal earnings growth	-0.98	21.96	-282.28	433.45	-2.04	16.80	-186.94	162.61
ΔTradable earnings growth	0.33	8.19	-81.18	94.64	0.42	5.44	-66.67	57.04
ΔNon-tradable earnings growth	-1.66	17.39	-281.42	431.34	-2.57	14.04	-182.86	166.65
ΔEPW growth	-1.25	10.76	-102.62	98.15	-1.78	7.80	-98.61	54.06
ΔTradable EPW growth	-1.74	33.96	-713.54	363.68	-2.56	23.63	-238.53	211.87
ΔNon-tradable EPW growth	-1.43	10.73	-117.72	114.53	-1.92	7.48	-101.69	60.16
ΔEmployment growth	0.16	13.48	-141.48	172.41	-0.19	11.69	-151.40	122.84
ΔTradable employment growth	0.49	5.98	-75.09	57.36	0.57	3.44	-30.92	36.55
ΔNon-tradable employment growth	-0.48	10.67	-148.78	172.70	-0.81	10.11	-146.16	124.68
Explanatory variables								
ΔEnergy earnings growth	0.35	5.65	-69.77	88.08	0.12	2.63	-74.11	65.67
ΔEnergy employment growth	0.15	2.46	-35.26	43.32	0.05	0.89	-16.08	19.95
ΔEnergy earnings growth, neighbouring counties	11.24	230.76	-7,502	11,155	1.61	58.15	-1,290	923.62
ΔEnergy employment growth, neighbouring counties	4.81	147.70	-5,897	7,511	0.62	16.53	-496.27	324.17
Boom	0.52	0.50	0.00	1.00	0.48	0.50	0.00	1.00
ΔEarnings IndMix	-1.21	10.00	-38.78	54.11	-0.85	11.22	-28.36	34.61
ΔEmployment IndMix	0.62	7.65	-29.65	42.04	0.82	8.34	-17.69	24.60
Control variables								
Share of mining, 2001	18.00	14.57	0.00	70.38	18.69	12.23	0.06	79.40
Share of agriculture, 2001	4.83	6.52	0.00	67.12	1.85	3.36	0.00	38.50
Share of manufacturing, 2001	2.63	7.03	0.00	95.52	1.04	3.77	0.00	60.27
Industrial diversity, 2000	8,503	570	1,955	9,228	8,769	511	1,536	9,311
Share of adults with less than HS, 2000	24.13	8.95	3.67	65.30	19.83	7.52	3.04	49.55
Share adults with BA, 2000	9.71	3.95	0.00	40.02	13.21	5.64	2.47	36.55
Share adults with grad and prof degree, 2001	4.65	2.27	0.90	36.03	7.10	3.98	1.80	30.56
Population (ln), 2001	9.64	1.04	4.19	12.12	11.37	1.33	7.42	16.08
Instruments								
Percent	0.1521	0.3293	0.0000	1.0000	0.1516	0.3309	0.0000	1.0000
Oil	0.0002	0.0014	0.0000	0.0400	0.0006	0.0083	0.0000	0.1994
Miles	0.0004	0.0008	0.0000	0.0097	0.0003	0.0007	0.0000	0.0075
Observations	6,018				3,165			

Appendix F

Table 1F. OLS estimation results for tradable total earnings by region

Explanatory variable	*Rocky Mountain Bakken*		*Rocky Mountain Niobrara*		Mideast Marcellus		Southwest Oil	
	Nonmetro	Metro	Nonmetro	Metro	Nonmetro	Metro	Nonmetro	Metro
ΔEnVar	.042	-3.7***	-.092***	-.19	-.04	.17**	-.071***	-9.2e-03
	(0.03)	(0.61)	(0.03)	(0.20)	(0.11)	(0.06)	(0.02)	(0.02)
ΔWEnVar	7.9e-03*	.046	-5.9e-04	-.039	-7.0e-03	.014	1.7e-03***	3.2e-03**
	(0.00)	(0.03)	(0.00)	(0.03)	(0.02)	(0.03)	(0.00)	(0.00)
Boom	-.14	.4	.68**	-.049	-.059	.072	4.8e-03	-.19
	(0.51)	(0.54)	(0.26)	(0.24)	(0.43)	(0.21)	(0.78)	(0.32)
ΔIndMix	.28***	.065	.25**	.33	.77***	.48***	.53***	.28***
	(0.07)	(0.14)	(0.10)	(0.21)	(0.09)	(0.11)	(0.11)	(0.06)
Mining2001	6.3e-03	.092	-.014	.02	-.05***	-.012	-.016	-.021
	(0.03)	(0.06)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Observations	771	144	777	162	837	765	1,275	519
R2	0.062	0.318	0.062	0.101	0.199	0.248	0.153	0.217

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; standard errors in parentheses; all models include a full set of controls as described in Section 3 (*Mining2001, Agri2001, Manuf2001, Diversity2001, LessHS2000, BA2000, GradProf2000, LgPop2001* and time period dummies).

Table 2F. OLS estimation results for non-tradable total earnings by region

Explanatory variable	*Rocky Mountain Bakken*		*Rocky Mountain Niobrara*		Mideast Marcellus		Southwest Oil	
	Nonmetro	Metro	Nonmetro	Metro	Nonmetro	Metro	Nonmetro	Metro
ΔEnVar	.5**	-4.4**	.64***	2.3	-.21	-.26	.2***	.061
	(0.22)	(2.05)	(0.14)	(1.63)	(0.20)	(0.17)	(0.06)	(0.11)
ΔWEnVar	.021***	.17***	.026***	-.028	.12*	.14***	4.2e-03***	.014
	(0.00)	(0.06)	(0.01)	(0.04)	(0.06)	(0.03)	(0.00)	(0.01)
Boom	.72	2.6***	-.44	.51	2.4**	.47	.27	2
	(0.84)	(0.89)	(0.75)	(0.75)	(1.07)	(0.60)	(1.03)	(1.41)
ΔIndMix	1.3***	1.4***	1.9***	1.2***	.66***	.66**	.9***	1.1***
	(0.23)	(0.35)	(0.40)	(0.39)	(0.11)	(0.26)	(0.23)	(0.23)
Mining2001	-.084*	.033	-.03	-.049	-.015	.066**	-8.4e-04	-.02
	(0.05)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)
Observations	771	144	777	162	837	765	1,275	519
R2	0.208	0.508	0.263	0.479	0.160	0.216	0.094	0.444

***, **, * - significant at 0.01, 0.05, and 0.1 respectively; standard errors in parentheses; all models include a full set of controls as described in Section 3 (*Mining2001, Agri2001, Manuf2001, Diversity2001, LessHS2000, BA2000, GradProf2000, LgPop2001* and time period dummies).