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December 2015

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(December 2015)

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Abstract

The U.S. shale boom has been joined by many other countries producing various unconventional fossil fuels (UFF) in the past decade. This new UFF industry differs from previous energy extraction by its rapid growth and sparse geographic nature, making the analysis of its socioeconomic consequences for extractive regions key for better regional planning and policy making. As such, the shale literature has boomed in recent years with numerous empirical studies evaluating and analysing different socioeconomic impacts from across the globe. This paper provides the first in-depth literature review of the growing body of empirical studies analysing the local impacts of shale (and other UFF) extraction, especially examining employment, income, population, housing, human and social capital effects and the co-existence of the industry with other productive activities. We find a quite surprising range of findings that in several occasions are contradictory, prompting more questions to many important issues. Given this broad range of results, we also focus on critical empirical considerations within this literature that are important to consider in future quantitative assessments of UFF impacts. Finally we provide some policy considerations and lines of future research.

1. Introduction

In the early 2000s, a group of entrepreneurs employed an innovative method that combined hydraulic fracturing and horizontal drilling to extract natural gas and oil trapped in shale formations in an economically feasible manner (Wang & Krupnick, 2013). Since then U.S. shale gas and oil extraction has grown rapidly and other regions around the world are also starting to see expansion of this new energy extraction industry. In addition, other unconventional drilling for fossil fuel has surged, including coal seam gas (CSG, a.k.a. coal-bed methane gas) extraction in Australia, tight oil in the U.S. and Argentina, and tight gas in Egypt and Indonesia (EIA, 2015).

The global and national macroeconomic effects, as well as environmental consequences and risks, from unconventional fossil fuel (UFF) extraction are multiple and complex. They have gained increasing attention in the literature (e.g. Jacoby et al., 2012; Simshauser & Nelson, 2015); however are out of the scope of this study. In this paper, we focus instead on reviewing literature addressing local and regional socioeconomic consequences the UFF industry has brought to regions and communities sitting above endowments. This is a critical issue as the extraction of UFF is generally a spatially extensive action – numerous drilling points and wells are required across space to economically retrieve resources trapped in formations – therefore likely to directly and indirectly affect millions of people across the world (Measham & Fleming, 2014a).

Empirical research evaluating local consequences of the gas/oil shale extraction boom has also boomed in recent years. These studies have used different methods and geographic locations to address impacts of the industry on different socioeconomic phenomena. In this paper we examine this broad line of research and provide a critique of what is available so far. We perform this literature survey with three main objectives. First, to the best of our knowledge, this is the first comprehensive literature review of scientific quantitative studies in this emerging research field. In light of this, we provide an assessment of what has been evaluated so far and a synthesis of the main findings. Second, we discuss and criticize important empirical issues present in several of our reviewed studies and focus on their limitations and potential for robust assessment of impacts. Third, we summarize, suggesting new lines of research and policy implications.

1.1. Literature review considerations

Reports, consulting briefs, and similar "non-academic" studies measuring the local/regional economic impacts of the UFF industry are abundant and available for many areas of the world. Nevertheless, we mostly ignore this literature because it often lacks scientific rigor. We focus instead on surveying empirical quantitative studies published in peer-reviewed journals, as well as academic working papers available online. Although abundant, the UFF literature is relatively young. However, there exists a large body of studies examining the regional or local socioeconomic consequences of conventional energy extraction and mining industries. Many of these studies provide important insights into the UFF domain, so we consider many of them as relevant for our discussion.

The first review of UFF studies dates back to 2011 (Kinnaman, 2011) and covers regional economic impact studies written by 2009 – when the industry was starting to gain momentum. However, in contrast to our research, Kinnaman focused his review on non-peer reviewed reports, which in 2009 outnumbered the scientific peer-reviewed literature. More recently, Kelsey et al. (2015) and Mason et al. (2015) also reviewed the shale literature. However, the former study focuses on establishing best practices to avoid a natural resource curse, rather than providing a comprehensive review, while the latter attempts to provide a broad review of the economic and environmental impacts of shale, but misses most of the regional/local socioeconomic impacts literature, therefore neglecting several of the critical points we discuss here.

It is important to highlight that we base our literature review on empirical studies, predominantly with evidence assessed through quantitative methods. While most studies surveyed in this paper have an economic basis, we have also added a few select studies employing qualitative analysis, based on their novelty or relevance to our discussion.

2. Review on local socioeconomic impacts of unconventional fossil fuels development

The recent UFF boom differed historically from other booms as it produced a widespread geographic footprint in just ten years. This boom has mainly been driven by technological advancements rather than market stimulation, which suggests an even more unexpected (exogenous) intervention in many areas. Its implicit exogeneity, proximity to inhabited and productive places, and wide geographical footprint makes the UFF boom a very interesting research topic for impact assessment and evaluation across socioeconomic dimensions.

In the following we subdivide our survey into five main components. Following the hierarchical flow of effects proposed by Measham et al. (2015), the socioeconomic impacts reviewed are given by: primary employment and income effects; secondary effects given by population changes and housing effects; and finally tertiary effects given by alterations to human and social capital and the UFF economic co-existence with other industries.

2.1 Employment and income effects

The literature on the impacts of mining on local areas suggests that extraction industries have different impacts on employment and income across regions surrounding extraction sites. Many factors such as local policies, the volatility of commodity prices, job spillovers, crowding-out, agglomeration and income effects can produce different outcomes for regional economies (Fleming et al., 2015; Allcott & Keniston, 2014). In the case of UFF the initial period of construction (mainly drilling wells and placing pipelines) can create a multitude of new jobs directly and indirectly working in the extraction industry. The local labor demand shock for workers during the construction drives wages higher and can increase the income of nearby residents as well as generating job spillovers into non-mining sectors. However, regions with unconventional resource extraction can also suffer from labor crowding-out in non-tradable sectors as workers move to the more financially lucrative UFF sector or to industries linked to the activity. Thus, the initial labor demand shock produced by the extractive industry, and linked changes in income and employment in other sectors, are initial effects and key to better understand and measure.

2.1.1 *Direct employment*

At a national level the direct employment generated by the UFF industry is generally negligible. In the U.S., Kelsey et al. (2015) estimate that a total of 563,000 people were directly employed in the overall oil and gas sector (that is, including non-shale conventional extraction) in 2012, which was only 0.4% of the total U.S. labor market. However, even though the UFF industry is unlikely to generate significant changes in national labor markets, its regional effects can be quite important. Affected rural areas generally have small labor markets and a demand shock coming from UFF extraction expansions can completely change their dynamics.

Two main issues should be considered in the direct employment domain: the origin of the labor supply and the employment demand changes between the construction and operational phases. The former is important because the UFF industry, like the modern mining industry in general, may be supplied by workers commuting long distances (especially in remote regions). This process will affect extractive regions as well as regions where employees permanently reside. The latter issue is relevant as direct labor demand from the UFF industry declines once wells start producing. On the first issue, Wrenn et al. (2015) find that in the Marcellus Shale in Pennsylvania, only one-half of the total employment working for shale companies were residents of the same county where the extraction was occurring. For the second issue there is still not much evidence as the UFF boom is an ongoing process, although evidence from operations of shale companies show that from an initial labor demand of 9 to 13 full time employees (FTE) annually required for drilling and completion of wells, the use of labor drops to only 0.2 to 0.4 FTE once wells start producing (Brundage et al., 2011; Kelsey et al., 2015). Both Weber (2014) and Brown (2014) find that about 7.5 jobs are created in the mining sector for each billion cubic feet of gas production. In section 3 we highlight some of the challenges in quantifying direct employment effects of UFF given available data.

2.1.2 *Indirect and total employment*

Employment effects in other sectors are also important in considering the impact of the UFF industry on local economies. Indirect employment coming from the supply chain and inputs for the industry, or crowding-out and job spillovers into other sectors, can be important for extractive regions and key for overall employment growth assessments (Allcott & Keniston, 2014).

In an analysis of both the early and more mature phases of the shale industry, Paredes et al. (2015) find that there was a relatively small overall increase in total employment from the Marcellus Shale over the years 2004 to 2011. These authors use the number of unconventional wells spudded to measure the location and magnitude of UFF activity in the Marcellus region, finding the average drilling-stage employment effect from UFF to be approximately 71 to 181 jobs per boom county, which is relatively small. On the other hand, they do not find any employment increase in dynamic models used to examine the operational phase. Similarly, Cosgrove et al. (2015) also consider the Marcellus region and leverage a natural experiment between PA, which allowed UFF extraction, and New York state (NY), which imposed a moratorium on the UFF industry. The authors do not find a statistically significant total employment effect in boom counties. However, several studies do find a positive total local employment effect from shale development in the U.S., for example in the south-central U.S. (Weber, 2014), the central U.S. (Weber, 2012; Brown, 2014), and for the continental U.S. (Weinstein, 2014; Maniloff & Mastromonaco, 2014). In particular, Maniloff and Mastromonaco (2014) estimate that the shale boom has created approximately 220,000 local jobs in boom areas.

Spillovers can also happen in sectors not directly linked to extraction activity. For example, higher spending in local areas as a result of higher disposable income can generate spillovers into some non-traded sectors of a local economy. UFF salaries are generally higher than those offered by agriculture, manufacturing or services in regional areas, which also explains potential negative job spillovers – or crowding-out effects – on the traded sector, as workers will tend to move between sectors towards the better-paid UFF industry. Thus, it is useful to consider how both the traded and non-traded sectors are affected by the UFF boom.

In Australia, Fleming & Measham (2015) find no crowding-out effect on manufacturing employment, but do find that for every new CSG job generated in the Surat Basin in Queensland, 1.8 agricultural jobs were lost. As Weinstein (2014) points out, energy sector growth may be crowding out agricultural jobs that may have been lost anyway due to labour-saving productivity growth. In the U.S., several studies have found that either the shale boom produced a beneficial employment spillover to the local non-traded sector or did not negatively affect the traded sector, or both (Weber, 2014; Brown, 2014; Weinstein, 2014; Komarek, 2015a; Maniloff & Mastromonaco, 2014). Allcott & Keniston (2014) use data from the Census of Manufacturers and found that the traded manufacturing sector can grow as firms supply inputs to the extraction process. In contrast, comparing PA to NY, Cosgrove et al. (2015) found evidence that the tradable manufacturing sector has contracted as a result of the UFF boom. DeLeire et al. (2014), using quantile regressions and synthetic controls also find contraction in traded-good sectors in the Marcellus Shale.

It is important to note that multipliers can vary over time. Tsvetkova and Partridge (2015) find that nonmetropolitan U.S. oil and gas employment multipliers vary from about 1.3 in one-year periods to over three in six-year periods, before returning to about 1.6 for ten years (or as low as near zero at ten years). These results suggest that spillovers first rise over time as supply chains develop and deepen, but then decline as other types of economic activity are crowded out.

2.1.3 Income effects

There is almost unanimous evidence that UFF, on average, produces increases in the income of residents of endowed regions (Fetzer, 2014; Maniloff & Mastromonaco, 2014). Local income effects come from two main sources: new and higher salaries triggered by the UFF industry, and non-salary revenues in the form of compensation and/or leases paid by the industry to landowners (Mason et al. 2015).

Given the labor demand shocks produced by the UFF boom, higher salaries are a likely immediate consequence for extraction regions. For the case of CSG in Australia, Fleming and Measham (2015) find that families residing in coal seam gas areas received on average 15% more income than families in other parts of the state between 2001 and 2011, which came mainly from wages and transfers made for access to extraction points. In the U.S., Munasib & Rickman (2015) also find positive effects on per capita income, although values are small. One paper finding no income effects is Paredes et al. (2015), which found no robust evidence of a positive income effect generated by the boom in the Marcellus Shale. This is despite the authors exploiting a comprehensive revision of income data collected by the Bureau of Economic Analysis which expands coverage to royalty income from mineral extraction.

An interesting observation of the UFF boom has been the large number of landowners that have received compensation from gas companies, due to the geographically overarching nature of the industry. In many cases, landowners have received significant revenues from relinquishing mineral rights and/or permitting access to extraction sites. Fitzgerald and Rucker (2014) estimate royalty payments for natural gas production to private landowners in the U.S. as slightly less than 0.1% of total U.S. national income, but in some states the payments are closer to 0.5% of state income. Similarly, Brown et al. (2015) estimate that the six major U.S. shale plays generated $39 billion in private royalties in 2014. Feyrer et al. (2014) estimate that, in the producing county and nearby counties (within a 160 km radius), royalty payments exceed $150,000 per million dollars of oil and gas produced.

Looking at tax returns in PA, Hardy and Kelsey (2015) claim that most of this new income from UFF leases and royalties goes to mineral right owners, but these are generally concentrated in a few hands, consequently increasing income inequality across communities.

2.2 Population and housing effects

As many rural areas around the globe face population decline due to migration to cities, the population gains that nonmetropolitan regions can have from UFF development is an interesting phenomenon to track. However, modern labor markets and modern transport systems have led the mining industry to utilize long-distance commuting workers. The opportunity to retain or attract people to rural areas (especially youth, women and skilled people) is not necessarily easily achievable with the new UFF expansions.

On migration, Measham & Fleming (2014b) find a positive effect of the CSG boom in southern Queensland, which they claim has even increased the number of skilled young women, in comparison to other rural regions in the state. Finding a small positive effect, Tsvetkova & Partridge (2015) found that for every 100 new oil and gas jobs in a U.S. nonmetropolitan county, about 20 new residents migrated to the county. On the other hand, several studies do not find a migration effect. For instance, James and Smith (2014) examined the Mountain West region (including Colorado, Wyoming, North and South Dakota and Montana), finding that unconventional resource extraction did not have a significant impact on population. Likewise, Munasib and Rickman (2015) find no population gains in UFF regions across the U.S. On the contrary, Brown (2014) did find positive population growth across the nine natural gas states he studied in the U.S., but he does not differentiate between extraction and urban areas, which is important as there is likely great heterogeneity in the ‘tails’ such as the relative population explosion in the sparsely populated Bakken region.

Regardless of the final change in population, the development of any type of resource extraction will inevitably affect local housing markets. Theoretically, housing impacts of resource development involve several effects: (1) an increase in housing values as higher disposable income and likely population increase in resource-rich regions increases housing demand; (2) the market value of some properties may increase due to the expectation of compensation for the extraction of subsoil endowments or access to extraction points; (3) a decrease in housing values of properties located near extraction points, as negative externalities from resource extraction will affect property values[1]; and (4) the bust of commodity cycles can translate into a local oversupply of housing, negatively affecting values. A final consideration is that the capitalized value of a house equals the long-term capitalized values of user costs and price appreciation. Since a boom is by its nature short-term, it is not clear that a boom would affect long-term values unless there was some long-term expectation that the growth was permanent. However, the extent to which these effects are realized will depend on the region’s specific characteristics and on how points (1) to (4) play out.

On positive effects on housing, Weber et al. (2014) find Texas property values are higher in zip codes with shale, which the authors hypothesized to be driven by local public finances. Boslett et al.(2014) find that houses in NY would have gained value in the range of 7 to 10% had NY not imposed a moratorium on hydraulic fracturing. These authors estimate this potential gain by comparing border counties between PA (counties with shale activity)

[1] Negative externalities include traffic, noise, night lights and possible environmental risks such as water table contamination, among others.

and NY using a hedonic price framework and over 16,000 property value data points. On the other hand, Muehlenbachs et al. (2014) found that houses with piped water presented small gains in property values as a result of lease payments, and that property values increased when shale gas wells were drilled in the general vicinity of a property (i.e. within 20 km), however this only applied in the first year that wells were drilled.

Finding a modest effect, Farren et al. (2013) find that the Pennsylvania UFF boom had a minor effect on housing prices, rental prices, and new housing starts, which the authors argue may be due to UFF-affected rural communities experiencing population decline during the boom phase, while for some UFF-affected suburban counties near Pittsburgh the relative scale of the economic activity caused by UFF development was too small to have a discernible impact. Similar results were found by Muehlenbachs et al. (2015) when looking at increased house rents in PA versus the ones in NY state. In UFF counties of Colorado, the hedonic modeling of Bennett and Loomis (2015) found a modest positive effect on house prices as a consequence of increased employment in oil and gas. In any case, to the extent that booms and busts are capitalized into the housing market, Muehlenbachs et al. (2014) claims that evidence suggests that booms are short-lived for housing prices, which after a couple of years return to normal market conditions.

As consequence of negative externalities (point (3) above), households may see their property values decline when extractive wells are located close to the property, but not close enough for compensation to be offered. Employing a hedonic estimation using over 4,000 data points on property transactions, Gopalakrishnan and Klaiber (2014) find that close proximity to a shale gas well (0.75 miles) reduces property values by between 1% and 8% in Washington county (PA). In their empirical assessments, houses with private well water suffer more value loss than others, a finding also supported by Muehlenbachs et al. (2014) using a 2 km distance from a well as the band for capturing externalities. Bennett and Loomis (2015) find a small negative effect on prices of urban houses located in the (half a mile) proximity of shale wells (–1% in the price for each well being drilled). Muehlenbachs et al. (2014) also find that wells that were permitted but have remained undrilled have a negative impact, which increases with the length of time since the permit was granted.

Delgado et al. (2014), using different hedonic price models and over 7,000 property value observations across two different counties of PA, found no important links between shale development and property values.

Finally, it has been shown in the resources literature that housing value gains made during a boom can be lost in the bust. Once the boom is over or the need for many workers subsides much of the infrastructure built in boom times becomes either obsolete or left underused. There is a decrease in housing prices and increased pressure on those left in the area to maintain them (Christopherson & Rightor, 2012). Given the current expanding stage of the industry, not much of this evidence is yet available for the UFF context.

2.3 Impacts on human and social capital

Effects of resource extraction activity on human capital have been widely reported in the literature. The main finding is that mining reduces the marginal benefits of education with an abundance of low-skilled jobs that affects the local skills and young people's aspirations to obtain education, as well as entrepreneurial spirit (Betz et al., 2015; Glaeser et al., 2015). There is an emerging line of research aiming to evaluate whether the shale boom is associated with human capital impacts across regions. Looking at resident populations, Weber (2014) considered changing educational attainment in the adult population in a four-state region in the U.S., finding that the shale boom did not erode local human capital stock. In particular, there was not a statistically significant increase in the adult population with less than a high school education, while the population of high school graduates and those with some college increased slightly. Considering education and skills in post-secondary youth populations, Measham and Fleming (2014b) found that regions with CSG development in Australia had attracted skilled young populations to reside in these regions, leading to higher proportions of youth with university degrees and advanced technical qualifications compared to other rural regions without CSG development. One likely reason is that at least during the boom phase, energy development is associated with a large number of highly educated technical and engineering workers.

Marchand and Weber (2014) investigated two different lines of inquiry on human capital effects. The first was that increased labor demand could pull students and teachers out of schools to work on energy projects. The second was that the increased tax base available to schools could enhance teacher quality and student productivity. Considering these relative to the shale boom in Texas, the authors find that schools with increased revenues in boom regions invested resources into capital projects but not teachers; they further find that boom regions tended to have higher turnover among teachers and particularly among less experienced teachers, and that economically disadvantaged school students were entering the labor market. Overall they found that shale development was linked to decreased student achievement, despite the abundant resources available to schools.

Other indirect impacts of resource extraction activity include disturbances to local social capital due to higher incomes and new temporary and/or permanent migrants. For UFF, a vast qualitative body of literature exists which looks at boomtown effects such as social conflicts, crime and substance abuse. On quantitative empirical grounds, Komarek (2015b) brings together various theoretical links between resource extraction and crime, from the criminology and economics literature, to examine how crime was affected by drilling in the Marcellus region of PA. The author finds that there was an increase in violent crimes (sexual and aggravated assaults) in local areas attributable to the UFF boom. James and Smith (2014) find that UFF boomtowns might act as a magnet for certain types of criminals. For example, using sex offender registry data, they find that boomtowns disproportionately attract convicted felons, though it might be that labor shortages in boomtowns mean that the industry lowers hiring standards to attract labor. Ruddell and Ortiz (2014) provide descriptive results that suggest mixed evidence, mainly a statistically insignificant association, for the effect of a UFF boom on property and violent crime rates for counties in Montana and North Dakota. These last researchers use several empirical methods to measure this relationship; however, the analysis suffers from data limitations that resulted in small samples.

2.4 Co-existence with other industries

There is significant discussion of whether the UFF industry can coexist with other productive activities competing for land, such as cropping, livestock and forestry. On the likely impacts of the shale industry to agriculture, Hitaj et al. (2014) highlight four main outcomes: (1) Greater demand for water from the UFF industry could cause farmers to transition from water-intensive crops to crops requiring less irrigation or none at all; (2) Increased dust from UFF construction and traffic can negatively affect crop and livestock productivity. (3) Higher revenues from compensations and royalties; and, (4) Labor costs increase as consequence of unskilled labor demand from the UFF sector.

On the initial outcome, Hitaj et al. (2014) found that states with shale development have seen their irrigated land decrease.[2] The issue of dust effects has been investigated less in the case of UFF, though there is empirical literature showing that dust does negatively affect farms' productivity, albeit slightly (Fleming & Abler, 2013). Royalties and compensation, on the other hand, are more complex and can be a much bigger issue. Just in the U.S., for instance, Hitaj et al. (2014) report that in 2011, energy lease and royalty payments to farmers amounted to $2.3 billion, which is close to half of all the value of payments provided by the USDA's direct payment commodity program. However, how much of these royalty revenues go to agricultural investment and how much go to other assets is an open question.

Finally, on labor effects, as discussed previously there is evidence that UFF development causes wage increases, which crowds out labor from tradable goods sectors such as agriculture. In Australia, Fleming and Measham (2015) found a reduction in jobs in the agricultural sector as a product of the CSG expansion, which they claim relates to substitution of more expensive labor by capital (machinery), made possible by the higher disposable income available to farmers from UFF industry compensation. In the remote U.S. state of North Dakota, the Bakken Shale region has been facing a considerable shortage of seasonal workers, so most farmers are resorting to using foreign migrants (Hitaj et al., 2014).

3. Methods revision and empirical challenges

Although different empirical strategies exist to apply regional economic evaluations of resource booms and busts, our review shows that most empirical studies are inclined to use ex-post econometric evaluations. This tendency reflects the limitations of using Input-Output (I-O) and computational general equilibrium models (CGE) approaches. Although a very

[2] However, in some cases as the CSG experience in Australia, a by-product of gas extraction is subsoil water extraction from aquifers, which has translated to more water available for agricultural production in the short term (DEHP, 2014).

popular method employed by industry and governments to measure economic impacts, I-O models can easily provide misguided results, especially in the context of resource extraction activity (Moretti 2010; Kinnaman, 2011; Fleming & Measham 2014), while CGEs are hard to implement in regional contexts and their use is not common among academics as data and parameters necessary to construct CGEs across regions (such as parameters on local migration, commuting and firm elasticities) are generally hard to obtain. On the other hand, econometric models are easy to implement and if conducted correctly, can identify actual economic impacts of booms, although with limited structural interpretation. Of course, econometric approaches are never exempt from empirical caveats and considerations. In the following sections, we discuss key empirical issues related to econometric methods employed across our reviewed literature.

3.1. Measures of energy intensity to evaluate impacts

To measure UFF effects on employment, wages, migration, etc. there has been some discussion of proper measures of energy to use as variables in regional econometric models. So far, studies have used five main variables: (1) oil and gas employment intensity (e.g. Weinstein, 2014; Tsvetkova & Partridge, 2015); (2) oil and gas production (output) (e.g. Weber 2012, 2014); (3) measures of oil and gas reserves (e.g. Michaels, 2011; Fetzer, 2014); (4) production/number of wells (e.g. Paredes et al., 2015); and (5) location of wells (e.g. Fleming & Measham, 2015; Gopalakrishnan & Klaiber, 2014).

Using energy employment has the key advantage of directly measuring how much the labor market is affected by UFF development, in that theory of regional natural resource curse suggests that natural resource sector labor demands force up wages and other input costs, making other sectors less competitive and crowding out labor from other local industries (Fleming et al., 2015). Thus, knowing the relative size or change in the size of the energy sector is important. Likewise, since multipliers or migration responses to economic shocks directly relate to the size of the shock, knowing the amount of energy employment directly addresses these types of questions. There are shortcomings with using energy employment in econometric analysis, especially given by data availability. However, when data is available across regions it is also important to consider whether observations are from residential or place of work data (Wrenn et al., 2015).

When appropriate data are not directly available some studies replace oil/gas employment data with total mining employment data. The issue here is that in some regions data on changes in mining employment would not necessarily correlate with changes in oil and gas employment. Although it may be expected that during the initial stage in a UFF boom, the vast majority of changes in mining sector employment would be dominated by changes in oil and gas employment, in some cases the presence of other types of mining activity can distort estimates.

The problem with place of residence data is that people often commute to their place of work, which could mean a researcher would attribute the impact of mining to the residential location of the worker. This may not be severe if we are talking about activities such as retail or manufacturing, in which long-distance commuting or fly-ins are considerably rarer. However, it could be problematic in the case of mining regions where it is more common for workers to "fly-in" to their remote place of work while living far away. Because of that, some of the effects of mining may be understated because the share of workers officially residing in the locality of the mine site can be relatively low, while places without mining may appear to experience some of the related effects because "place of residence" data on workers employed in mining picks up such workers.

In the case of variable (2), some studies use production (output) data as a proxy for employment (Weber, 2012, 2014; Brown, 2014)). But the main question in this case is whether changes in oil and gas production/outputs are useful as a proxy for changes in oil and gas employment. Kelsey et al. (2015) note that, using PA Marcellus Shale data, about 80% of direct employment due to oil and gas extraction occurs during the construction boom associated with drilling and the build-up of infrastructure such as drilling pads, roads and pipelines. Another 18% is during the pre-drilling phase due to activities such as securing leases and drilling rights and early infrastructure build-up. Only 2% of employment is after the drilling phase because it does not take very many workers to watch over producing wells with fully-developed infrastructure. Certainly with conventional wells, in which sustained production can last for decades, changes in production would have very little correlation with employment changes over most of the production cycle. With unconventional production, production typically greatly declines over the first few years and there is a need to reapply the fracturing process to continue production, which means that there is some employment necessary for this "re-drilling". However, since the drilling pad and associated infrastructure are already in place, the associated employment increase is much less than during the initial drilling as all that is needed is a reapplication. Thus, the correlation between production changes and employment growth would likely be much smaller as oil and gas booms mature, even when production rises.

Illustrating the problems of using output data, Weinstein and Partridge (2014) find that the correlation between changes in total employment growth and changes in oil and gas production turns *negative* after dropping the two highest natural gas producing counties in the U.S. Likewise, when they regressed the change in mining employment on the change in oil and gas production (and their squares), the associated R^2 was only 0.021, illustrating a very weak relationship.

On the use of variables of type (3) – resource reserves – in a seminal paper, Michaels (2011) used initial oil reserves at the beginning of the 20th century to examine how the south-western U.S. oil patch fared. Using reserves has some advantages in terms of exogeneity but as an indicator of how much an economy depends on resources, it has several shortcomings. Foremost, having reserves may provide little information about when or whether the resource was or will be extracted. Likewise, it is unclear how what effects reserves have when the resource is not being extracted. That is, when a location sits on top of reserves that are not being actively exploited (as was the case for most UFF reservoirs a decade ago), it is unclear whether there will be any tangible economic spillovers.

In the case of using the number of wells, variable type (4), Paredes et al. (2015) use drilling rigs as a proxy for oil and gas employment in their assessment of the industry. It is also unclear as to the correlation of drilling rigs with oil and gas employment, though it is likely to be highest in the initial drilling/construction phase, weakening thereafter.

The spatial location of wells (4) is a useful tool for evaluating treatment effects, although as we discuss below endogeneity should be taken into consideration. Beyond aggregated/regional distinctions of well locations, the use of variables looking at the specific location of UFF wells is generally employed in case studies of hedonic evaluations. Future studies could consider how wells are distributed across land, especially considering that new technology may require much less concentration of wells.[3] This is important for evaluation, as in some cases high concentration of land ownership will be highly correlated to concentration of revenues flowing from UFF companies to communities, which will mask income and employment distributional effects and likely increase income inequality in local economies (Hardy & Kelsey, 2015).

3.2 Issues when measuring job multipliers

Bartik (1991) describes a very simple and powerful econometric way to measure job spillovers, given mainly by regressing the difference of the studied sector by the "predicted" shift-share job growth in the sector producing the spillovers (see also Moretti, 2010). Focusing on the mining industry, Fleming and Measham (2014) adapt this econometric approach and discuss its implications for resource extraction economies. Similar methods employing employment growth are used in different UFF studies (e.g. Deleire et al., 2014; Weinstein, 2014; Fleming & Measham 2015; Tsvetkova & Partridge, 2015;).

Another way to approach multiplier estimation for the gas industry is proposed by Weber (2012, 2014), who instead of employment growth uses production data to estimate how much employment is generated by x amount of dollars' worth of gas extracted. However, when one indirectly estimates employment multipliers using production data, one is taking a noisy estimate of employment (as discussed above), which is likely to create very imprecise estimates (Kelsey et al., 2015).

One question that has generated some confusion in interpreting multipliers is at what level does an increase in oil and gas employment *actually increase* the diversity of a locality's

[3] Multi-well pad technology means that several wells can be combined into a single point at the surface (Knudsen et al., 2012). This reduces the level of surface disturbance, which may be an advantage to other land uses. However, it may also reduce the level of compensation available to landholders.

economic structure? The issue is important as it has long been postulated in the regional and urban literature that a more diverse local economy outperforms otherwise equal local economies (Li et al., 2015). Indeed, a key feature of natural resource curse stories is that greater reliance on the volatile natural resource sector will harm economic growth. Weber (2014) contended that increases in oil and gas employment in the southwest U.S. were associated with the affected economies actually being *less* dependent on the oil and gas sector. The basis for his assessment was that the estimated oil and gas employment multiplier was 2.4. When looking at raw levels, it is true that with this estimate, employment levels grew faster outside the energy sector, but dependence is virtually always measured in employment shares. When considering employment shares, a multiplier of 2.4 implies that increases in oil and gas employment would asymptotically increase the oil and gas employment share to about 42% of the local economy (1/2.4). However, when compared to the local nonmetropolitan counties that were to experience the UFF boom, their 2001 oil and gas employment share was only 1.3%. Such a pattern would hardly be interpreted as suggesting less oil and gas dependence. Weinstein and Partridge (2014) show that the multiplier would have to be at least 77.0 for increases in oil and gas employment to *reduce* dependence on the sector (1/.013).[4]

Another issue is the determination larger national or regional impacts from local estimates. For instance, aggregating their local estimates up, Feyrer et al. (2015) using production data estimated that the U.S. fracking boom had increased U.S. aggregate employment 725,000 and reduced the national unemployment rate 0.5%. However, one needs to be very careful when extrapolating up to the aggregate level from local estimates. In Feyrer et al.'s (2015) case, assuming that their identification process using production data correctly

[4]For an increase in a sector to reduce dependence on that sector, the multiplier would have to be greater than 1/(sector's initial employment share).

estimated 725,000 local jobs when aggregating their local estimates, then it would be true that local employment in affected areas would be 725,000 more than the counterfactual of no fracking boom. Yet, for the nation when considering the counterfactual of no-fracking, then many of the people who got jobs in oil and gas regions would have been employed either in other sectors or for migrants to the these regions, they would have been employed in their origin region or other regions. Thus, while it is likely such estimates are large overestimates on national employment effects, it is generally true that the 725,000 people are better off in the oil and gas sector than in their next best alternative employment/nonemployment case.

3.3 Robustness when using IV and differencing approaches

As with mining in general, energy extraction is “exogenous” as the location of the industry is set by natural resource endowments, international prices and technology (operating costs). However, the exogeneity of the UFF boom and other mining booms may be affected by local regulations, or the business climate could affect drilling. If this is the case, as in some states of the U.S. that have embraced shale in contrast to others that have banned such activity (like New York state), regression problems emerge, requiring the use of an instrumental variable (IV) procedure to remove unobserved heterogeneity.

Geological instruments for energy production were introduced by Black et al. (2005) in terms of using coal reserves. In oil and gas research, some studies have used geological measures as instruments, but Weber (2012) appears to have been the first to appraise the regional effects of UFF activity – namely the percentage of the county that covers shale resources. Geological instruments seem to be conceptually the perfect instrument as it would seem intuitive that the only way oil and gas geology affects total economic outcomes is indirectly through affecting the intensity of oil and gas employment, which is the definition of a good instrument.

A less likely, though possible, problem is that there are omitted time-variant factors that are correlated with oil drilling. In this case, fixed geological measures of resource quality could have different effects depending on other conditions such as exogenous changes in world energy market prices or new developments in oil and gas drilling technology such as ongoing improvements in hydraulic fracturing. In this manner, Tsvetkova and Partridge (2015) interacted geological measures of oil and gas reserves and historical drilling intensity with year dummies to account for year-to-year changes in the price and cost of resources, finding the instrument set to be strong.

The question is whether IV is really necessary if accounting for fixed effects may provide sufficient in tangibly eliminating the omitted variable bias. In other words, if the main unobservables are relatively constant or persistent over time, differencing and controlling for key initial conditions would solve the primary cause of this bias.[5] In this regard, Weber (2012) employed a Hausman test to argue that the IV approach was superior to the OLS approach, though Tsvetkova and Partridge (2015) find that after first differencing, the Hausman test was generally insignificant. Given these results, it is not surprising that unlike Weber (2012), Tsvetkova and Partridge find that the OLS results were very similar to the IV results. The conclusion is that it is unclear that IV approaches are necessary to estimate the effects of UFF development if fixed effects are accounted for. Nonetheless, given the inconclusive results, researchers should test whether omitted variable bias is a real concern before embarking on IV approaches.

[5] Differencing procedures have advantages over fixed effect models in that there are weaker exogeneity conditions between the residuals and the explanatory variables across all time periods (Wooldridge, 2010).

3.4 Considerations when using counterfactuals

In the surveyed literature, many studies exploit quasi-natural experimental conditions, given by UFF subsoil reservoirs, to assess treatment effects – where "treatment" comprises the regions hosting the development of UFF across space (Weber, 2012; Fleming & Measham, 2015; Paredes et al., 2015).

Matching approaches try to compare treated groups (e.g. those with extraction development) to otherwise equal nontreated groups. Looking at conventional energy effects, Marchand (2012) compares rural municpality outcomes in the (treated) oil-rich Canadian province Alberta to the nearby (mostly untreated) prairie provinces of Saskatchewan and Manitoba. He finds that Albertan municipalities tended to outperform during oil booms, though there was no difference during oil bust periods, suggesting oil and gas development supports long-term growth. However, assuming Saskatchewan and Manitoban rural muncipalities are a good match for rural Alberta may be problematic as the latter province has a long tradition of pro-business governments and its agriculture is more livestock-oriented compared to the heavy grain production in Saskatchewan and Manitoba—i.e., we would expect rural Alberta to outperform the other regions without oil. In the UFF literature, several papers have used the context that much of PA and NY cover the natural gas rich Marcellus Shale, but NY state has placed a moratorium that has stopped virtually all drilling (e.g. Muehlenbachs et al., 2014; Paredes et al., 2015; Crossgrove et al., 2015). Comparing Western NY outcomes to PA outcomes appears to represent a good way to assess the effects of shale development, though this relies on the assumption that there are not other unobservables that differ between the two states, which might be questionable. To address matching considerations, Munasib and Rickman (2015) use a synthetic control approach to construct a composite match across nontreated locations, which is akin to propensity score approaches that put a higher weight on more similar locations in forming a match.

Summarizing, judging matching versus IV (or first differencing/fixed effect) approaches, the choice somewhat boils down to a researcher's *a priori* beliefs about whether the key differences across "treated" and "nontreated" regoins are observable, which suggests matching can be effectively employed, or whether they are unobservable, suggesting IV should be employed. The problem with matching is that there are no clear tests to show that the supposed untreated regions are true counterfactuals aside from balancing tests.

4. Concluding remarks, remaining questions and policy implications

Despite the large and growing literature, the phenomenon of the UFF boom and its effects on the wellbeing and living standards of millions of people residing in extractive regions is still far from being completely understood. Even in the (apparently) straightforward analysis of employment impacts, findings across studies are sometimes contradictory. However, what seems to be crystal clear is that the employment contribution of the UFF boom can be considerable for residents only if long-distance commuters are not the predominant labor force. On the other hand, indirect jobs generated as spillovers from UFF activity into other sectors are commonly modest; they vary over time and in some cases can even be negative. In terms of income, on average, local wages and family incomes have increased as a result of the UFF boom, although new evidence suggests that this is not evenly distributed and income inequality is increasing in these areas, especially in the U.S.

Population has seen also different patterns, but the normal trend has been very small population changes on average as a product of the UFF boom. Thus, while there are outliers where boomtowns rose out of the prairie, the evidence of low population growth as product of the UFF means that with relatively few in-migrants moving to take the jobs, if long-distance commuting is not the norm then unemployed original residents, or original residents who out-commuted disproportionately, are taking new jobs generated by UFF expansion. This implies that many original residents benefit, at least in the short term. With respect to housing, the finding that property prices are volatile as a result of UFF booms suggests some inefficiency in the housing market. Prices reflect long-term valuations which should only be modestly affected by short-term boom-bust conditions. However, what is clear from the existing evidence is that, at least in the short to medium terms, rents, house prices and land prices have often increased in UFF regions, so existing house/land owners can profit by renting and/or selling properties in these areas. However, this price increase also depends on how close properties are to extractive wells, as the evidence shows that extraction negatively affects housing prices if houses are located close to wells on land patches that are not entitled to compensation.

On human capital, the research is still young. Although there exists a large body investigating the impacts of mining on educational outcomes, the particular effects of UFF have been less explored. Findings so far show how initial stocks of educated populations have not negatively changed as consequence of the UFF boom, and have even increased in some cases (like in Queensland, Australia), and that local investments in education have not produced meaningful results for educational achievements. However, all these human capital focused studies miss the analyses of whether the UFF boom has affected the real demand for education. Social capital, on the other hand, appears to have deteriorated as consequence of the UFF boom in the form of more social conflicts.

4.1 Policy and future research

An important difference for policy and planning regarding UFF stems from the relatively sparse nature of the development. Whereas conventional energy extraction processes, such as coal mines, are concentrated in relatively small areas, UFF is more widely dispersed, such that it may affect wider populations and is more likely to be co-located with other land uses such as agriculture, therefore with greater chance of impacts which need to be managed through compensation or other mechanisms (Measham et al., 2015). Compensation claims may extend well beyond immediate extraction points to include a dispersed system of transport and infrastructure associated with movement of gas and waste products, which may interfere with existing regional economic activity. Policies and planning frameworks must consider ways to manage new types of environmental risks, new social tensions and the economic consequences of these. As UFF continues to expand world-wide, particularly in Europe, Latin America or South East Asia, it may come face to face with different types of land uses – from irrigated rice farming to aquaculture. An important need for research will be to assess the extent to which UFF is compatible with these land uses, and if they are co-located, what types of policies promote co-existence in these diverse contexts.

Finally, to date, there is very little published research on how unconventional fossil fuel extraction is experienced when inevitable busts set in. Even with the low international gas prices observed at the time of writing, the UFF expansion has not fundamentally halted, though it has greatly slowed. This is partly due to the relatively recent development of the technology and the abundant reservoirs awaiting to be exploited. Thus, understanding the socioeconomic effects of unconventional energy in a post-boom environment presents an important challenge for future research. It would be especially interesting to analyse whether UFF extraction becomes more or less compatible with other economic sectors such as agriculture and local manufacturing, and with educational investments, among others, over time.

Acknowledgments

The authors thank Karin Hosking for editorial support and Alex Dudley for initial research assistance. David Fleming and Tom Measham acknowledge support from *CSIRO Minerals Resources*. Mark Partridge acknowledges the *U.S. Department of Agriculture* AFRI Grant: Maximizing the Gains of Old and New Energy Development for America's Rural Communities.

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