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The economic impact of shale gas extraction: A review of existing studies ☆

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ABSTRACT

Recent advances in drilling technology have allowed for the profitable extraction of natural gas from deep underground shale rock formations. Several reports sponsored by the gas industry have estimated the economic effects of the shale gas extraction on incomes, employment, and tax revenues. None of these reports has been published in an economics journal and therefore have not been subjected to the peer review process. Yet these reports may be influential to the formation of public policy. This commentary provides written reviews of several studies purporting to estimate the economic impact of gas extraction from shale beds. Due to questionable assumptions, the economic impacts estimated in these reports are very likely overstated.

Contents

1. Introduction

Natural gas has historically been extracted from shallow gas wells using traditional drilling methods. Within the past decade, technological advances such as hydraulic fracturing and horizontal drilling have for the first time made profitable the extraction of natural gas from deep underground shale rock formations. Both economic benefits and environmental risks of such nonconventional gas extraction accrue to regions within close proximity of shale gas deposits. Site preparation, drilling, and extraction generate local economic revenues and provide local employment opportunities. But the drilling process requires large quantities of water and the backflow (frac water) requires careful handling and can threaten the natural environment.

Due perhaps to uncertainties over the size of these economic benefits and environmental costs, public response to the new extraction process has varied. Areas familiar with the gas extraction industry such as central Texas and western Pennsylvania have applied existing environmental and safety regulations to the new extraction methods. But New York, where the energy industry is relatively unknown, placed a moratorium on shale gas extraction until it has sufficiently studied the environmental risks.

To help facilitate favorable public policy, the natural gas industry has sponsored several research efforts that estimate the economic benefits of shale gas extraction. These reports, not published in economic journals but instead made available on the web sites of the gas industry, estimate the increase in local and state revenues, employment, and tax revenues from gas extraction. In some cases, these reports are authored by private

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consulting firms. In other cases, these reports are authored by research economists serving as private consultants and affiliated with well known research universities. In these latter cases, the economist's institutional affiliation is often featured prominently on the cover to add credibility and sense of objectivity to the report even if the economic researcher relinquished final editing duties to the funding organization. One concern for the objective formation of public policy is the possibility that local policymakers view the institutional affiliation of the private consultants as evidence that the report represents credible peer reviewed economic research. If those policymakers are unacquainted with the economic research methods used in these reports and are therefore unable to judge the validity of the results, then the economics profession has not served the policy making community.

This commentary reviews a collection of reports purporting to estimate the economic impact of gas extraction from shale beds. The focus is on reports sponsored by the gas extraction industry and issued with academic institution affiliation. For example, Considine et al. (2009 and 2010) were both funded by the Marcellus Shale Coalition (the shale gas extraction industry in Pennsylvania) and feature the Penn State logo on the title page. CBER (2008) was sponsored by four gas extraction firms and features the University of Arkansas logo on the title page.

The hope is to help fill the void created by the lack of a peer review of these reports. The credibility of economic research originates not from institutional affiliation but from the peer review process utilized by all respectable academic journals. This review process ensures fairness, promotes the candid exchange of ideas, and often improves the quality of the work.

The next section summarizes and critiques these three reports. Section 3 provides a brief overview of other known economic impact studies from gas extraction generated from private consulting firms unaffiliated with academic institutions. Section 4 offers a broad critique of the methodology used by these six reports to evaluate "economic impact." Section 5 discusses benefit-cost analysis, a common alternative method for evaluating the economic impact of an activity such gas extraction. Section 6 offers a comment on the use of a severance tax on gas extraction, and is followed by a brief conclusion.

2. Reports Released with Academic Affiliation

A delineation is made between three reports that were released under academic institution affiliation (Considine et al., 2009, 2010; CBER, 2008) and three that were released by private consulting companies unaffiliated with an academic institution. The delineation is based upon the premise that institutional affiliation can denote the expectation of unbiased and high quality research to policy makers and other readers. The institutional affiliation carries with it the expectation that research should satisfy not just the standard for reports from the consulting industry, but instead achieve some higher level of academic standard.

2.1. An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play

Considine et al. (2009), affiliated with Penn State, estimates the economic benefits of extracting gas from the Marcellus Shale in western and northern Pennsylvania. Pennsylvania is depicted to be rather unique in the United States due to its (1) supplies of natural gas both in shallow wells and imbedded in deep shale formations, (2) availability of subterranean reservoirs to store natural gas imported from the southwest United States for later consumption, and (3) proximity to several large population centers along the eastern sea board. This latter aspect has caused the price of natural gas in Pennsylvania to generally exceed that in most other areas of the country.

The economic impacts of shale gas extraction are estimated using the IMPLAN input–output model. The IMPLAN model has been used by consultants, government officials, and economic researchers to address a variety of research questions. Because shale gas extraction is relatively new to the Pennsylvania economy, the IMPLAN model had to be adjusted using a process developed by Miller and Blair (2009). This process requires detailed expense amounts from the industry. This information was gathered via a survey of firms currently in the process of extracting gas from the Marcellus shale. Based on responses to this survey, the report estimates that 95% of industry spending occurred within the commonwealth of Pennsylvania.

IMPLAN results suggest spending by the shale gas extraction industry is responsible in 2008 for $2.263 billion in economic activity, the creation of 29,284 jobs, and the payment of $238.5 million in state and local taxes within the commonwealth of Pennsylvania. The report also estimates the number of new wells drilled as a function of the price of natural gas using quarterly time series data from Barnett shale activity in Texas. Econometric results suggest a 1% increase in the price of natural gas is estimated to increase the number of new wells drilled by 2.70%. This estimate and future price data from the New York Mercantile Exchange are then used to forecast the number of wells drilled in Pennsylvania over the next decade. Results suggest the number of wells drilled in Pennsylvania will increase from about 1000 in 2010 to 2800 in 2020. These results are applied to estimate the effect of a severance tax on gas extraction in Pennsylvania. Results suggest a tax set equal to that levied in West Virginia will cause the number of future wells drilled to decrease by 30%.

Several aspects of Considine et al. (2009) are credible. The historical and technological sections appear to report an accurate background of the industry. The survey data had a rather poor response rate (only 7 of 36 firms responded), but as these firms represented 59% of all drilling in Pennsylvania it is appropriate to extrapolate survey findings to the entire industry. It is worth noting that itemized industry expenses with names and locations of suppliers are highly proprietary information. A research economist unaffiliated with the gas industry would not gain access to such data. The IMPLAN model, as mentioned by the authors, is perhaps the most common input–output model in the country and is used by consultants, government officials, and research economists. The technique described by Miller and Blair (2009) for estimating direct spending of a new industry is appropriate assuming that itemized expense data are available, as they were for this report. One concern is that the IMPLAN model works best when considering modest "marginal" changes in economic activity. The addition of billions in direct spending will likely alter the relationships within the model that could very easily alter estimated impacts.

The report has three major shortcomings that all serve to overstate economic benefits that would need to be addressed to warrant journal publication. The first is the assumption made that all lease and royalty payments to private households are spent by households on goods and services produced in Pennsylvania in the same year that those payments were received. The importance of this assumption cannot be understated—in 2008 such payments to households represented 68.6% of all industry direct spending. Households can be expected to save some of these windfall earnings. Given the fluidity in the international market for financial capital, additional savings by Pennsylvania households are unlikely to be lent to Pennsylvanians to facilitate increase investment or consumptive expenditures within Pennsylvania. That *none* of these windfall earnings are assumed to be saved (or used to pay down debt) by households seems implausible and is inconsistent with the economics literature. The behavioral economics literature, for example, contends that households are more likely to save (or reduce debt) after receiving large windfall payments relative to receiving small sums (Thaler, 1990). An economic impact study of shale gas extraction in Louisiana (Scott, 2009—summarized below) assumed that households spend only 5% of windfall earnings within the year received. This report should use a more realistic assumption regarding the marginal propensity to consume windfall gains. Although the present estimated economic impacts would obviously decrease substantially, future impacts would likely increase as the spending from household lease and royalty payments received

in the present are spread across many future years rather than spent entirely in the present year.

The second shortcoming in this report is the lack of a detailed description to support the assumption that 95% of all industry expenditures, including lease and royalty payments to households, occurred within Pennsylvania. The survey helped identify the location of suppliers to the industry, but payments to suppliers comprise only 31.4% of all spending. Households receive the lion share, and any amount not saved may have facilitated purchases of goods or services produced outside of Pennsylvania (such as vacations, new automobiles, or jewelry). The report suggests the "company profile databases Reference U.S.A." was used to determine the geographical location of each firm receiving direct spending. But the report is silent on the assumptions necessary if, for example, a given firm operated only a branch office in Pennsylvania but imports parts and supplies from other states or countries. One report suggests that 70% of workers in the industry originate from other areas of the country (Allegheny Conference, 2010). The assumption that 95% of direct spending by the industry and royalty-receiving households took place in Pennsylvania is therefore under supported. A detailed description of the process used to identify the location of direct spending would alleviate this concern.

The third shortcoming, one that I am sure the authors would agree with, is the assumption made that the quantity of well drilling is estimated solely as a function of the contemporaneous price of natural gas. The assumption that the price of natural gas is exogenous in Texas is entirely plausible, but omitted variables are quite likely to lead to a biased estimate of the relationship between price and well drilling. Omitted variables could include the expected future price (which could influence both current price and investment expenditures on drilling), the state of drilling technology, the state of the macro economy, and the number of wells drilled in a previous period (suggesting a time series). That the number of wells drilled in Texas had to be "calibrated" for use in Pennsylvania is highly suggestive that variables other than the current price explain drilling quantity and that these variables take on different values in Pennsylvania than they do in Texas. These other variables could very easily be correlated with price, implying a bias in the estimated coefficient on price. Because the econometric model is utilized to estimate the effects of a severance tax on natural gas, a discussion that could influence public policy, greater attention should be devoted to estimating an unbiased relationship between price and well drilling. The current estimate is unconvincing and potentially misleading.

Also, in the tax section, the comparison between Pennsylvania and West Virginia is fragile. Certainly differences other than the regulatory climate between the two states describe differences in gas extraction, such as the proximity to major markets along the east coast. The report does not provide convincing evidence that conditions experienced in West Virginia are the direct consequence of a severance tax.

2.2. The Economic Impacts of the Pennsylvania Marcellus Shale Gas Play: An Update

Considine et al. (2010) updates the economic impacts of shale gas extraction on the Pennsylvania economy. The Penn State logo is again featured prominently on the cover page. This update is also based on a survey of firms in the industry. But rather than asking firms to report detailed expenses as was done for the original report, the updated survey asks firms to provide spending levels in a few broad categories (lease/bonus spending, exploration costs, drilling expenses, gas processing costs, royalties paid and other spending). Results from this survey suggest spending in these categories increased from $3.22 billion in 2008 to $4.54 billion in 2009. This increase in spending is attributed to increases in drilling expenses and gas processing expenses in 2009.

The expense reports gathered for the original report (Considine et al., 2009) were used as a benchmark to allow IMPLAN to estimate the economic impacts. Results of the IMPLAN model suggest the Marcellus gas industry contributed $7.17 billion to the Pennsylvania gross output—implying a spending multiplier of 1.90. This multiplier is about 25% higher than that found for other shale industries in the country—the authors attribute this difference to the accuracy of each surveyed firm's expense report relative to past studies. A second estimate of economic impact, the value added to the Pennsylvania economy from the gas industry, is estimated at $3.88 billion in 2009. The value added metric subtracts inter-industry purchases from gross output. The industry is also estimated to have contributed 44,098 jobs to the Pennsylvania economy in 2009 and paid $389 million in state and local taxes.

This report also estimates the quantity of natural gas produced in Pennsylvania over the coming decade. The number of vertical and horizontal wells drilled in 2010 and 2011 are estimated based on industry responses to the survey. The number of wells drilled beyond 2011 is based upon the econometric model reported in the original 2009 report and discussed above. This model forecasts that 3500 wells will be drilled in 2020. Based on these assumptions, the report suggests natural gas production in Pennsylvania will increase from 1 billion cubic feet per day in 2010 to 13.5 billion cubic feet in 2020. The economic impact of this gas production is estimated at $18.85 billion in value added, $1.87 billion in state and local taxes, and nearly 212,000 jobs in 2020.

All three shortcomings that weakened the validity of the first report are imbedded in this update as well. The assumption is still made that all lease and royalty payments are spent by households within the year they are received, the assumption that 95% of all direct expenses occur within Pennsylvania is still made, and the econometric model used to forecast the quantity of well drilling solely as a function of the contemporaneous price of gas is still applied. These three shortcomings, once again, potentially undermine the accuracy of all results.

2.3. Projecting the Economic Impact of the Fayetteville Shale Play for 2008–2012

CBER (2008) estimate the economic impact of shale gas extraction in Arkansas. The report features the logo of the University of Arkansas on the cover page, but adds a disclaimer that although the gas industry sponsored the research, the conclusions reached were not influenced by outside parties. This research is based on a survey of several firms extracting gas in Arkansas, and as above uses the IMPLAN model to estimate the effect of gas extraction on economic output and employment. Specifically, shale gas extraction is estimated to increase gross revenues in the state of Arkansas by $2.6 billion in 2007 and generate 9533 jobs. These impacts are also forecasted for years 2008 through 2012. These forecasts are based on planned investments as identified by industry in the survey.

This study also estimates the impact of a severance tax on natural gas extraction. Rather than relying on a potentially misspecified econometric model, this study utilizes responses from the industry survey. One survey question asked firms how a 5% severance tax would affect planned investment expenditures. Responses suggested firms would decrease investment expenditures by an average of 13%. For comparison, Considine et al. (2009) estimate a 30% reduction in investment expenditures from the severance tax.

3. Other Studies of the Economic Impact of Shale Gas Extraction

Three similar reports use the same approach as that used in the reports discussed above to estimate the economic impact of shale gas extraction on state and local economies. These reports are issued by various consultants that are not affiliated with a prestigious academic institution. One of these reports estimates the economic impact for the state of Louisiana (Scott, 2009), one for the Dallas-Fort Worth regional economy (The Perriman Group, 2009) and one for Broome County, NY (Weinstein and Clower, 2009).[1] Table 1 summarizes the

[1] For convenience, all of these reports can be accessed at http://groundwork.iogcc.org/topics-index/shale-gas/topic-resources (accessed 7/13/2010).

Table 1
Other studies, a comparison of assumptions.

Shale play	Estimated impact	In the year	To the economy of	Assumptions
Marcellus	$4.2B in output 48,000 jobs	2009	Pennsylvania	100% royalties spent immediately "The locations of all these suppliers and income recipients were determined using the company profile databases Reference U.S.A. and Manta, which also provided the economic sector for each purchase" (95% of direct spending in state)
Marcellus	$8.04B in revenues 88,588 jobs	2010	Pennsylvania	100% royalties spent immediately "The locations of all these suppliers and income recipients were determined using the company profile databases Reference U.S.A. and Manta, which also provided the economic sector for each purchase" (95% of direct spending in state)
Barnett	$11B in revenues 111,131 jobs	2008	Dallas/Ft. Worth Area	"The amounts were fully adjusted to reflect those funds that are paid outside the region (and state) and are further reduced to account for out-of-area spending, savings, and taxes."
Hayensville	$2.4B in revenues 32,742 jobs	2008	Louisiana	All direct spending in state Assumes households spend 5% of lease and royalty payments in 2008.
Fayetteville	$2.6B in revenues 9533 jobs	2007	Arkansas	Survey asks firms to report state of residence of employers, but not whether spending occurs in state or out of state.
Marcellus	$760M in revenues 810 jobs	2000 wells over 10 year period	Broome County, NY	Assumptions regarding percentage of drill spending in local economy not stated
Marcellus	$2.06B in revenues 2200 jobs	Gas production per year	Broome County, NY	Assumes 15% of royalty earnings remain in local economy

findings of all six reports. Included in the table is a description of each report's two assumptions regarding direct industry spending. The first assumption is what percentage of direct industry spending is assumed to occur within the state or local economy. Recall that the two reports summarized above assumed 95% of all direct spending occurs within the commonwealth of Pennsylvania. The assumption that most or all spending occurs within the local or state economy is shared by most of these other reports. One report assumed that only 15% of direct industry spending occurred within Broome County, New York (this study is also the only to delineate between the economic impacts of drilling and that of extraction).

The second key assumption is what percentage of lease and royalty payments are saved by households. The reports above and almost all reports summarized in Table 2 assume all lease and royalty payments received by households are spent in the year in which they were received. The Louisiana study is unique by assuming households save most of these windfall earnings and spend only 5% each year.

One additional report not summarized in Table 1 also estimates economic impacts (Murray and Ooms, 2008). Rather than using a model such as IMPLAN to forecast economic impacts, this report compares historical data on population, incomes, and employment over a 16 years in four regions of the country. The first studied region is Denton County in Texas where gas has been extracted from the Barnett shale since 2001. The second and third are Faulkner County and White County in Arkansas within the Fayetteville shale play. Gas exploration began in this region in 2002 but only 180 wells have been drilled as of 2006. The final region is the counties that comprise the 10th Congressional District in northeast Pennsylvania, where only limited shale drilling occurred prior to 2006. The data provided are divided into two periods. The first period is 1990–2000 when none of the regions experienced gas drilling or extraction. The second time period is 2000 to 2006 when gas extraction was active in three of the four regions. Differences in growth rates of populations and per-capita incomes experienced in counties with and without gas extraction serves as a crude estimate of the economic impact of shale gas extraction.

Table 2
Average annual percent increases. (bold implies active shale gas extraction).

Region	1990–2000	2000–2006
Denton County, Texas	Population ↑ 5.8%	**Population ↑ 5.8%**
Barnett Shale (began 2001)	Median HH Income ↑ 5.8%	**Median HH Income ↑ 2.5%**
Faulkner County, Arkansas	Population ↑ 4.3%	**Population ↑ 2.8%**
Fayetteville Shale (began 2002)	Median HH Income ↑ 6.1%	**Median HH Income ↑ 1.5%**
	Employment ↑ 4.8%	**Employment ↑ 1.1%**
White County, Arkansas	Population ↑ 2.2%	**Population ↑ 1.3%**
Fayetteville Shale (began 2002)	Median HH Income ↑ 6.3%	**Median HH Income ↑ 2.1%**
	Employment ↑ 2.4%	Employment ↑ 0.5%
10th Congressional Dist, PA	Population ↑ 1.4%	Population ↑ 0.1%
Marcellus Shale (began 2006)	Median HH Income ↑ 4.0%	Median HH Income ↑ 2.5%

The authors of this report unfortunately draw the wrong conclusions by describing changes in economic variables in shale areas as "tremendous" and those in non-shale areas as "negligible". The data simply do not support these conclusions. Table 2 provides the average annual percentage change in population, median household income,[2] and employment in each of these four regions across both time periods used in the original report. Statistics marked in bold are assumed to represent regions or time periods where shale gas extraction was active. If gas extraction impacted the economy, then we would expect to see populations, incomes, and employment rise at greater rates in bold areas than in non-bold areas.

There are a host of economic variables that could explain differences in these variables across time, so comparing within-region statistics in the 1990–2000 period with those of the 2000–2006 period would yield no insight into the economic effect of gas extraction. The only way to make use of these data is to consider differences in differences. Did the local economies in Texas or Arkansas experience a different change from the early to the latter time period than the local economy in Pennsylvania?

In Denton County, the average annual rate of population growth did not change across the two periods. But in Arkansas, the average annual population growth rate decreased in the two counties by 1.5% (from 4.3% per year to 2.8% per year) and 0.9% (from 2.2% to 1.3%). Compare these experiences with the case in Pennsylvania where the average annual population growth rate decreases by 1.3% (from 1.4% to 0.1%). Assuming that no other economic or demographic variables affected Pennsylvania any differently than these other areas, then we can estimate that shale gas drilling increased the annual population growth rate by between 1.3% and a negative 0.2%.

[2] It is not clear in the report whether incomes were adjusted for changes in overall price levels (inflation).

But how much did these additional workers earn? In terms of per-capita incomes, all areas experienced a decrease in the average annual growth rate in the second period relative to the first. It appears the U.S. economy did not grow as strongly in the 2000–2006 period than it did in the 1990–2000 period. But surprisingly the average annual growth of per-capita income fell more sharply in the three counties with shale drilling and extraction than was experienced in Pennsylvania. The average annual growth of income decreased by 2.3% in Texas, 4.6% and 4.2% in Arkansas, but only 1.5% in Pennsylvania. Using the differences in differences approach, and again assuming that no other economic or demographic factors capita affect Pennsylvania any differently than Texas or Arkansas, we can only conclude that shale drilling and extraction activities *decreased* per-capita incomes by between 0.8% and 3.1%.

Thus, comparing the data in Texas and Arkansas with that of Pennsylvania crudely suggested that the impact on populations and per-capita incomes is negligible. Economic impact of gas extraction to the Pennsylvania economy could be quite small if (1) well drilling utilizes out-of-state economic resources, and (2) landowners save or spend their lease and royalty payments in other states or countries. The possibility of these two occurrences may not be remote.

But Pennsylvania is a rather poor control area. Regional economic and demographic forces are likely to affect the Pennsylvania economy and the Texas and Arkansas economies in separate ways. If one were to seriously utilize the differences in differences approach to estimate economic impact, then a county or counties not involved with shale gas extraction but within the south-central region of the county would serve as a viable control area. But, based on a misinterpretation of the data, this report adds very little to our understanding of the economic impact of shale gas extraction.

4. Critique of Methods Used to Estimate Economic Impact

Economists are often interested in evaluating the economic impact of an activity such as producing a good or service, completing an investment project, or implementing a public policy measure. A common goal of economic inquiry is whether the activity is economically efficient. An activity is deemed efficient if the value society places on the activity exceeds the value of all economic resources allocated to performing the activity. That is, the activity is deemed efficient if its benefits exceed its costs. Several research tools are available to economists to estimate both benefits and costs of gas extraction.

These reports, on the other hand, estimate economic impact of gas extraction by estimating the effect on gross revenues, jobs created, and tax revenue. The theoretical origins that justify this method of estimating economic impact were developed by John Keynes in the 1930's to explain and understand the Great Depression (Snowdon and Vane, 2005). A Keynesian economy arises wherever economic resources such as labor, capital infrastructure, and natural resources lay idle. The economy is not at full employment—surpluses of labor are evident and factories are operating below capacity. The economic solution to these economic episodes is to increase spending. Keynes called upon the Federal Government to initiate this spending, but the solution works just as well if the spending is initiated by a private industry. Keynesian theory suggests that initial direct spending will increase incomes that will consequently facilitate additional rounds of spending. Economic resources such as labor and capital will be put back to use to satisfy the new needs of consumers, and incomes throughout the economy will increase. It is these economic effects that these two reports attempt to estimate. Keynesian economics guided both government policy makers and many economists for most of the middle decades of the 20th century and receive renewed attention during the fallout from the recent financial crisis of 2008.

The weaknesses of the Keynesian view of the economy were articulated by economists such as Milton Friedman and other neo-classical economists (Carlson and Spencer, 1975). Friedman envisioned a limit for direct spending to increase incomes if economic resources such as labor and physical capital are fully employed. The Friedman economy made its appearance in the late 1960's and 1970's —when high levels of direct spending by consumers, firms and government stripped the economy of its economic resources and the resulting shortages caused prices to rise (inflation). Additional direct spending by the gas industry in such an economy would simply crowd out spending by other industries. The many firms servicing pad development, drilling, road construction, and frac water treatment and removal would be unavailable for other purposes. The economic impact of the shale gas industry on gross expenditures, jobs, and tax revenues would therefore be zero. The economy has simply shifted resources from the production of other goods and services towards the extraction of natural gas. Economic resources necessary to fuel a growing industry would either relocate from other regions of the country or shift from local industries within the region. The IMPAN model used to estimate these economic impacts largely ignores the possibilities of direct spending crowding out other users of the resource. For example, the hotels and restaurants that are at full capacity serving the gas industry are no longer available to tourists and other households. IMPLAN is not equipped to subtract the spending from the crowded out tourists and therefore can overestimate the economic impacts.

Thus, the economic impacts estimated in both reports are only possible in an economy operating below full employment. The recent direct spending from the gas industry during these past few years of recession could have increased incomes as reported, but as the economy recovers from the recent recession the economic impact could dissipate.

Another theoretical weakness of this method of measuring economic impact is the lack of economy-wide logical consistency. If an economist ran an IMPLAN model on every industry, the direct spending of each industry would be multiplied to estimate the effects on the economy. But as every industry claims responsibility for jobs and revenues in other industries that supply the industry, IMPLAN would estimate more economic activity than actually occurs. Undoubtedly there is an industry that could claim responsibility for jobs and revenues within the natural gas industry. The residential construction industry, for example, may claim that much of the spending on gas extraction was induced by the construction of residential homes. In the end, each industry is claiming partial responsibility for the spending of every other industry. But simple logic suggests things will not add up. Therefore, all impact statements based on input–output models such as IMPLAN are likely overstated.

The popularity of using models such as IMPLAN for estimating economic impact lies not upon its theoretical justification but upon its relative ease (inexpense) when compared to cost-benefit analysis described below. Estimating "local jobs created" also speaks the language of elected officials, who are often more interested in short term jobs reports than in the long term benefits that materialize with economic efficiency. The third convenient attribute to the IMPLAN method is the ability to separate economic impact to a specified region or state. This ability once again is helpful to state-wide politicians, who might care for more for the economy of their home state than the economy of neighboring states.

5. Cost-Benefit Analysis

The question most economists and long-term oriented politicians is whether the overall benefits of extracting the gas exceed the costs (Hahn, 2010). Unfortunately neither of these six reports addresses this question. This section outlines what a benefit-cost analysis of gas extraction from the Marcellus shale might look like.

The first and most obvious benefit of extracting natural gas is that natural gas is a source of energy useful for home heating, electricity

generation, and to the production process in many industries. The value the economy places on each unit of natural gas is measured hypothetically as the most a household or firm would be willing to pay (WTP) for each unit of gas. Whether the consumer of gas resides within the studied economy or not is not material to the analysis. This maximum WTP can be estimated by extrapolating from market data. We observe quantities falling when prices rise, so the maximum WTP was obviously exceeded by the price for at least some households, utilities, and firms. With sufficient variation in market prices and quantities, economists can estimate the maximum WTP (or "demand") for natural gas as a function of its price and other relevant variables. The literature is full of such research (Al-Sahlawi, 1989). These benefits to consumers of natural gas comprise by far the most sizeable benefit of gas extraction.

Another benefit unique to natural gas production (relative to the production of some other good or service) is the positive spillover effects from using a relatively clean source of energy. If increases in natural gas production reduce the demand for oil and coal, then for any given level of energy consumption, carbon dioxide emissions and other air pollutants such as sulfur and nitrogen decrease. Measuring this benefit is rather tricky, but papers in the economics literature have estimated the value of harm caused from carbon, sulfur, and other air pollutants (Smith and Huang, 1995). These results could be applied to estimate this benefit associated with natural gas extraction.

The costs of natural gas extraction include, perhaps paradoxically, all of the items listed as "benefits" in the six reports discussed above. Natural gas extraction requires labor, capital equipment, pipelines, and raw materials. These economic resources, in a fully employed economy, could have been allocated to other uses. The price paid to secure these resources from these other industries indicates the value of these resources to these other industries (had their value been higher, the market price would have been higher). Thus, the quantity of each economic resource times its market price – in fact the total expenses by the industry as gathered in the surveys – represents the cost of utilizing scarce economic resources to gas extraction.[3]

Another cost of natural gas extraction is the nuisance, noise, and loss of privacy to the owners of the property hosting the drill pads. Because land is privately owned and protected against unlawful trespass by our legal system, gas extractors can only enter land with permission from the property owner. This permission is granted only with sufficient compensation for losses resulting from the nuisance. In other words, the lease agreements and royalty payments paid to landowners serve as credible estimate of the nuisance cost of drilling for gas. This logic requires sufficient competition in the industry—gas extractors must have many property owners to negotiate with and property owners must have many gas extractors to negotiate with.

Third, the extraction of a nonrenewable natural resource such as natural gas creates user costs. Extracting the gas in the present imposes a cost to future generations who face lower stocks of the nonrenewable resource. These user costs are internalized by the gas industry if property rights for natural supplies of shale gas are well defined. If a particular extractor has secured a lease agreement to extract gas from a particular shale field, then the extractor claims ownership of that gas. With property rights secured and protected, the extractor will only extract the gas if the price received today exceeds the price expected tomorrow (after appropriate discounting). If the extraction occurs today, then the extractor has imposed a cost on itself because extracting today reduces the available gas to extract in the future. The tastes and needs of future generations therefore weigh upon the extractors decision to extract today, and user costs are internalized by the extractor. This user cost will cause the market price in the present to rise above the marginal current cost of extraction.

[3] Workers in a fully employed economy also need to be relocated and trained. This latter cost may not appear in the industry's expense reports.

If, on the other hand, rights to extract gas from any particular area are not well defined – perhaps gas migrates with changing subterranean pressures – then any gas left in the ground for future generations could be lost to the owner. The objective of the firm is to extract the gas as quickly as possible before someone else does. The costs to future generations are not considered in a "use it or lose it" environment, and market prices today will fall to the marginal current cost of extraction. In this case the user costs would have to be estimated separately for inclusion in the cost-benefit analysis.

The final cost of gas extraction is the value of all damages done to the natural environment (Weinstein and Clower, 2009). Hydraulic fractioning involves the use of water from local streams. The backflow (frac water) is radioactive and contains high levels of sodium and other elements that are dangerous to wildlife. The natural habitat surrounding well pads, service roads, and pipelines is segmented, which presents difficulties for many species. Add to this the vehicular traffic on roadways and the general nuisance to neighboring households that are not compensated by the industry. All of these costs are external to the market and must be estimated using imperfect but helpful economic research tools such as the hedonic pricing method, the contingent valuation method, or the travel-cost method.

To conclude, economists possess the tools necessary to estimate all benefits and costs associated with shale gas extraction. If the economic value of the gas exceeds the sum of the internalized production costs to industry plus the user costs plus the external costs, then the economic benefits of gas extraction exceed the economic costs. Gas extraction would have a positive *economic impact*, and the magnitude of this impact would depend upon the difference between the benefits and costs. Notice that jobs created, revenues generated, or taxes paid are not part of the analysis.

6. Severance Tax or Pigouvian Tax?

Many of these reports estimate the consequences to the industry and state economy from the imposition of a severance tax on natural gas extraction and perhaps other policy measures. Based on the imperfect econometric model described above (Considine et al., 2009), one result suggests that a severance tax could decrease gas drilling activity by 30%. But both omitted variables and econometric misspecification may bias this result. A second report (CBER, 2008) uses a survey of the industry to estimate drilling would decrease by an average of 13%. But until a better model is specified, we do not know with any confidence how industry will respond to a severance tax. For example, natural gas prices recently decreased by over 50% between the summer of 2008 and the late fall of 2009. These estimates predict a 150% to 300% reduction in well drilling. Yet, actual well drilling over this period in Texas and Pennsylvania did not decrease by any significant magnitude.

Economists generally support the implementation of excise taxes on industries that generate external costs to the environment (Baumol, 1972). The goal is not to transfer wealth from the industry to the state, but to encourage industries to internalize all costs of their production efforts. The optimal "Pigouvian" tax on each unit of gas extracted should be set equal to the marginal external cost that each unit of extracted gas generates. If firms respond to the tax by reducing gas extraction, then the social costs of that gas extraction (the costs to industry plus costs to others) must have exceeded the benefits of that gas extraction. Firms therefore over extract natural gas in the absence of the tax. Once the tax is implemented, the reduction in gas extraction, whether it is 13% or 30%, yields positive benefits to society. A tax set equal to the marginal social cost of extraction will encourage firms to extract the socially optimal quantity of gas. As an added benefit, the revenue generated from the severance tax can facilitate a reduction in income taxes. Many economists argue that income taxes slow economic activity (Bovenberg and Goulder, 1996).

7. Conclusion

This paper reviewed several reports estimating the economic impact from the extraction of natural gas from shale rock formations. The review is necessitated by the need to distinguish consulting reports released under academic institutional affiliation from peer reviewed economic research. Three shortcomings were identified from this peer review. These shortcomings could be corrected by (1) including better assumptions of when and where households spend windfall gains, (2) clarifying the process used to determine where suppliers to the industry and royalty earnings households are located (in state or not), and (3) developing a more appropriate econometric model to estimate well drilling as a function of current price and other relevant variables. Making these changes would likely decrease the size of the economic impacts estimated in these papers, but new estimates would likely be more accurate. Comments made throughout these papers that estimates are "conservative" are for the most part not appropriate and should be ignored. Given the assumptions made in relation to these three shortcomings, the estimates are very likely overstated.

If these reports are not widely read, then any harm done is inconsequential. But if institutional affiliation increases the exposure of these reports, then policy makers and other readers may be misguided by questionable economic estimates. Providing accurate estimates of the economic impact of shale extraction is important to the functioning of the state economy. Households and firms can be expected to base investment decisions on such forecasts, and overstating the economic impacts to persuade government officials could cause other disruptions in the economy if private investment decisions are based on poorly estimated economic impacts.

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