Opportunity Costs of State Regulation:
Accounting for the Economic Impact of a Shale Gas Well

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EXECUTIVE SUMMARY

- Shale gas holds the potential to increase U.S. energy independence as consumer demand shifts to this relatively abundant domestic supply. Increased utilization of America's natural gas endowment may help to reduce emissions associated with carbon-based energy consumption. The U.S. contains a sufficient supply of shale gas to enjoy these benefits for years to come.
- Shale gas production rose to over 20% of total U.S. domestic gas production in 2010, from less than 1% in 2000. And more than 10,000 shale gas wells were drilled in the U.S. in 2011, an increase in expenditures of nearly 90% from 2010.
- In states with shale gas resources, however, a number of regulatory initiatives can inhibit gas development. As of mid-year 2013, 38 states are debating new legislation of shale gas development activity. In total, 211 bills are currently under consideration at the state level. If passed, each of these laws will require a state-level agency to promulgate one or more regulations to ensure implementation of new legislation.
- A significant part of the opportunity cost of regulation is the economic benefits of the wells not drilled. For example, were New York State to lift the current moratorium on shale gas development, well drilling and producing cash flows would generate $4.5 billion of gross state product within three years and support a total of 39,000 jobs. After 10 years, drilling and producing activities would generate over $8 billion in economic activity, predominantly wage payments supporting nearly 69,000 jobs. This conservative estimate of prospective job gains is equivalent to 0.9% of current private sector employment in the state, or 9.5% of the unemployed workforce. These figures represent over three months of employment additions at New York's current rate of labor market performance.

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I. Introduction

The United States (U.S.) is abundantly supplied with natural gas locked in tight shale reservoirs. Technological advances in horizontal drilling and hydraulic fracturing have led to a boom in development of this domestic resource.[1] The U.S. Energy Information Administration (EIA) estimated proved domestic shale gas reserves of 97.5 trillion cubic feet (TCF) at year-end 2010.[2]

Shale gas holds the potential to increase U.S. energy independence as consumer demand shifts to this relatively abundant domestic supply. In addition, shifting to natural gas utilization may help to reduce emissions associated with carbon-based energy consumption.[3] The U.S. contains a sufficient supply of shale gas to enjoy these benefits for years to come. As a result, many analysts and policymakers believe that shale gas could serve as a cost-effective bridge to a future when renewable energy sources are more commercially sustainable.

In states with shale gas resources, however, a number of regulatory initiatives can inhibit gas development. Public concerns with water and air quality, safety, and quality-of-life issues have motivated a patchwork of regulations and regulatory proposals at the state level.[4] In some states, regulatory restrictions have largely blocked development of this valuable resource.

State policymakers everywhere desire to balance the costs and benefits of prospective regulation. And although prospective benefits may be unique to each specific regulatory proposal, a significant share of the costs are not dissimilar. A large part of the opportunity cost of prospective regulation is the value of discouraged economic activity. For example, each potential well that is not drilled represents lost jobs and employment income, lost income to mineral property owners, and lost business activity.

[1] Rogers 2011.
[2] EIA 2012.
[3] Carey 2012.
[4] Richardson et al. 2013; author query of the Advanced Energy Legislation Tracker, June 29, 2013; Linehan and Estefan global list of fracking bans and moratoria at keeptapwatersafe.org.

Policymakers who desire to understand the costs of shale gas regulations now have a wealth of information to aid in their decision making. "Shale gas production rose from less than 1% of total domestic gas production in the [US] in 2000 to over 20% by 2010."[5] And the U.S. drilled more than 10,000 shale gas wells in 2011, increasing expenditures by nearly 90% from 2010.[6] Because the cost structure of shale gas well development is relatively uniform, and because producers sell into national commodity markets, the benefits of these wells to their local and regional economies is similar in many respects.

This study illustrates how America's experience with shale gas activity can be used to understand the cost of discouraged development opportunities. We examine the cost structure and financial flows from a typical shale gas well. The framework suggested from our experience can be scaled to understand the magnitude of economic opportunities foregone when a regulatory regime effectively avoids all development activity. We utilize this framework to estimate the opportunity cost to New York State of their current moratorium on directionally drilled and hydraulically-fractured well completions.

Section II describes the shale gas opportunity. We discuss the geologic and geographic nature of the development, and the technological challenges of development and production.

Section III discusses the economic benefits from cash flows associated with shale gas development – the opportunity cost of prospective regulation.

Section IV considers the economic impact of shale gas development in Pennsylvania. In addition, we estimate the value of foregone opportunities in New York that can be attributed to that state's moratorium on shale gas development.

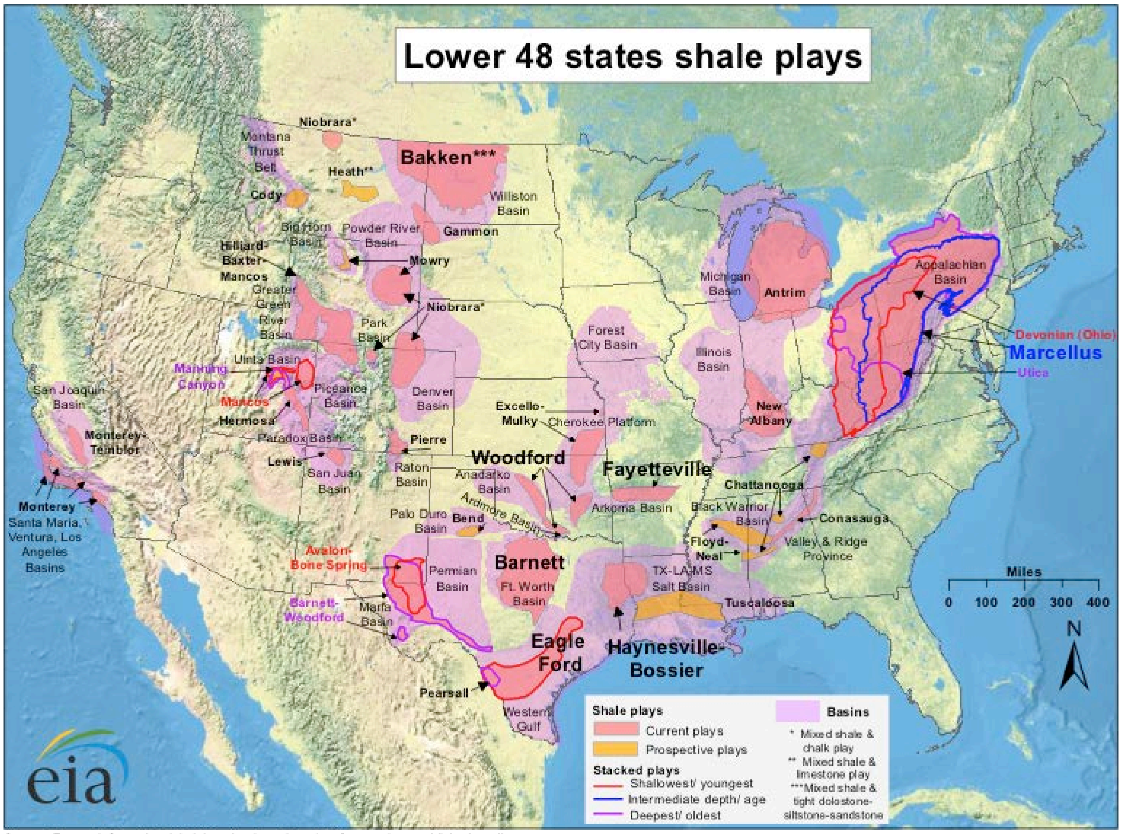
II. The nature of America's shale gas opportunity

The U.S. holds an abundant supply of natural gas, much of which is locked in tight shale reservoirs. Based upon a survey of domestic oil and gas reserves,[7] the U.S. Energy Information Administration, EIA, estimated commercially proved domestic shale gas reserves of 97.4 TCF at year-end 2010.[8] This represents an increase of over 300% from the 2007 proved

[5] Stevens 2012.
[6] Oil and Gas Journal 2013.
[7] Form EIA-23, Survey of Domestic Oil and Gas Reserves.
[8] EIA 2012, Table 3.

reserves estimate.[9] Proved shale gas reserves in 2010 accounted for 31% of total domestic proved natural gas reserves.[10]

Figure 1



Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

Estimates of technically recoverable reserves represent an estimate of the nation's maximum potential shale gas resource. The 2010 year-end resource estimate for technically recoverable total natural gas in the U.S. was 1,900 TCF.[11] According to the EIA, technically recoverable shale gas reserves were 482 TCF,[12] or 25% of total domestic technically recoverable natural gas reserves.

[9] Ibid, Table 13. According to the Society of Petroleum Engineers, "[p]roved reserves are those quantities of petroleum which, by analysis of geological and engineering data, can be estimated with reasonable certainty to be commercially recoverable, from a given date forward, from known reservoirs and under current economic conditions, operating methods, and government regulations."
[10] Ibid, Table 2.
[11] PGC, 2011.
[12] EIA, 2012.

U.S. shale gas reserves are also geographically diffuse (see Figure 1). Shale gas is found in regions familiar with energy extraction activities, such as Oklahoma and Texas, the Gulf Coast, and the Mountain West. But shale gas is also found in regions with much less recent experience as host to energy development activity. For example, the Marcellus formation underlies several states in the Appalachia region, extending from West Virginia, eastern Ohio and western Maryland, through much of Pennsylvania, and into upstate New York.

Understanding the challenges of shale gas development requires a familiarity with the geology of conventional sandstone hydrocarbon reservoirs. Conventional sandstone reservoirs are characterized by a large amount of void or 'pore' space. For example, the maximum porosity for sandstone of tightly-packed spherical grains of any size is 26%.[13] In practice, the grains in clean sand reservoirs may be arranged in ways that result in upwards of 30% pore space. That is, up to a third of a piece of clean sandstone may be void space, the space available to hold something other than rock. When this pore space is filled with gas, we call it a natural gas reservoir.

And this natural gas may move relatively freely through a conventional sandstone reservoir. Because the grains composing sandstone reservoirs are relatively uniform in size, sandstone reservoirs are also relatively permeable, containing many pathways that will permit fluids and gasses to flow. Consequently, in traditional sandstone natural gas reservoirs, a vertical well that intercepts only a small part of a reservoir may be able to produce much of the gas located throughout the vast void space in the reservoir.

In contrast to sandstone reservoirs, those composed of shale have relatively little pore space. For example, in a study of shale gas plays prepared for the EIA in 2010, the porosity in shale reservoirs around the U.S. varies from 2% to 12%.[14] Thus, a relatively large volume of shale is necessary to hold the same amount of gas that could be contained in a smaller sandstone reservoir.

On the other hand, unlike sandstone, the shale rock itself contains organic material, the source of the gas. Therefore, while the shale may have less pore space in which to hold natural gas, it has the potential to desorb more natural gas into that pore space as the existing gas is removed.

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[13] Bass, 1987.
[14] EIA 2011.

But removing the existing gas, and creating the conditions necessary for desorption of gas from the organic matter, is a relatively difficult process. Shale reservoir grains are unlike those clean, spherical grains found in a sandstone reservoir. Shale stone grains are relatively flat, less like spherical balls and more like flat cards. And when these grains are deposited, they are likely to be stacked in a manner that leaves relatively little void space (imagine a deck of playing cards scattered in a pile). In addition, the void space that does exist among these shale grain 'cards' is not necessarily connected. There are relatively few pathways through which the material in the shale void space may flow.

These physical properties of shale make conventional development techniques impractical for shale gas reservoirs. Conventional vertical wells will not connect to a volume of gas sufficient to justify the expense of development. Doing so requires creating pathways for flow through a vast volume of shale reservoir, and connecting those pathways to a wellbore. Developing America's shale gas resources presents some unique challenges that the industry has only recently begun to master.

Shale gas developers have employed two techniques to access volumes of gas sufficient to justify the expense of development. First, advances in directional drilling now allow developers to drill horizontally inside the reservoir. Horizontal drilling allows each well to penetrate a much larger section of the gas-bearing formation.

Advances in hydraulic fracturing have also been critical to enabling cost-effective resource development. Hydraulic fracturing creates pathways that connect the pore spaces in a shale stone reservoir. In addition, by creating a pathway to deplete the existing pore space, hydraulic fracturing enables further desorption of gas from the organic content of the shale. When this occurs, additional gas is released from the shale stone into the pore space, where it can flow through fractures to the horizontal well.

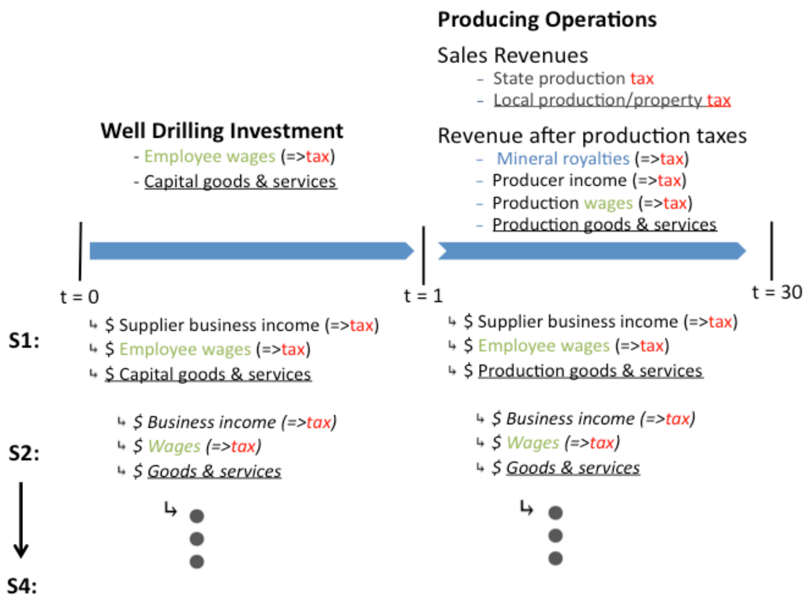
III. Opportunities and challenges of shale gas development

Development of America's shale gas resources promises a number of potential benefits. Investment expenditures and producing operations yield financial benefits to workers and property owners. And the country's natural gas resources represent an opportunity to increase energy independence and reduce the environmental impact of consumption.

However, a range of legislative and regulatory initiatives hold potential to limit full utilization of the nation's natural gas endowment.

The direct economic impacts of gas development are significant. Shale gas resource endowments motivate considerable investment necessary to covert resources in place to a useable commodity. Figure 2 symbolizes this pattern of development investment expenditures and operating cash flows for a single-well.[15]

Figure 2 – Well Drilling and Producing Operations Cash Flows



In the well drilling investment phase, depicted in time-period 0 in Figure 2, primary expenditures are made to wage earners and capital goods and services providers. For example, resource developers require various tubular products and drill site services.

Payments those primary suppliers are allocated as the cash flows as depicted in supplier level 'S1'. At each supplier level, cash flows are allocated to supplier business income, or the purchases of labor and goods and services enabling such business income. Funds flowing to goods and services providers are allocated to business income, wages, and goods and services at subsequent levels of suppliers.

[15] Note: this framework may be used additively in order to model the economic impacts of a multi-well drilling program.

The economic benefits from the investment period are followed by a relatively long producing life, with requisite expenditures on operations and support services. Shale gas well producing operations may remain profitable for 20 years, 30 years (as depicted in the illustration), or longer. Over that period of time, they will generate cash flows to a broad range of stakeholders.

Table 1 provides a detailed tabulation of primary cash flows during the producing operations phase symbolized in Figure 2. The boldface type entries demonstrate various economic stakeholders that may be identified from the producing operations cash flow statement. Taxes on production revenue flow to a variety of stakeholders at the state and local level. Mineral royalty owners receive a fraction of revenue net of production taxes. Mineral royalty recipients are often state residents, but they may also be parties who own property outside of their state of residence.

Table 1 Producing Operations Cash Flows
Production sales revenue
- **state production taxes**
- **local production / property taxes**
Revenue Net of Production Taxes
- **mineral royalties**
Revenue Net of Production Tax and Royalty
- **operating expenses**
- **SG&A**
- depreciation, depletion, amortization
Earnings Before Interest and Taxes
- **interest expense**
Earnings Before Taxes- income tax
- **business income tax**
Net Income

Operating expenses and administrative expenditures include both worker salaries, and goods and services purchased from suppliers. Worker salaries may be paid to both in-state and out-of-state workers. Payments for supporting goods and services may also remain in-state or flow to out-of-state suppliers. In either case, payments for goods and services result in indirect economic effects from producing operations.

Finally, as was the case in the drilling investment phase, payments to primary suppliers in each year of the producing phase are allocated as depicted in supplier level 'S1'. At each supplier level, cash flows are allocated to supplier business income, or the purchases of labor and goods and services enabling such business income. And those funds flowing to goods and services providers are allocated to business income, wages, and goods and services at subsequent levels of suppliers.

Development of natural gas resources can also yield a number of social benefits. Utilization of domestic resource endowments can improve energy security and reliability. For example, natural gas is increasingly utilized to satisfy demand for household heating and peak electricity generation. Increased use of natural gas to satisfy these needs has allowed a greater share of liquid petroleum production to be directed towards valued uses in transportation.

And because natural gas has a relatively low carbon content, utilization of this resource can yield environmental benefits. "Compared to the average air emissions from coal-fired generation, natural gas produces half as much carbon dioxide, less than a third as much nitrogen oxides, and one percent as much sulfur oxides at the power plant."[16]

Finally, because America's gas resources are abundant, analysts believe they may serve as a low-carbon bridge to a future of predominantly renewable energy supplies.[17] Many sectors are expected to increase utilization of relatively clean supplies of low cost natural gas.[18] And domestic gas supplies should be sufficient to support broad-based utilization for much of this century.

Realizing the benefits of an abundant resource endowment, however, necessitates development activity where the reserves occur. And given the diffuse nature of shale gas deposits, gas development activity is now occurring in many communities that have little

[16] US EPA 2013, as cited from the EPA's Emissions and Generation Resource Database.
[17] Song 2013.
[18] Kirkland et al. 2010.

recent experience with energy industry activity.[19] Moreover, even in states that are host to a vibrant energy sector, shale gas development is oftentimes closer to population centers than were conventional resources. For example, the Barnett shale underlies parts of the Dallas-Fort Worth metropolitan area, in contrast to conventional resource plays in rural west Texas, east Texas, and the Gulf of Mexico. Concerns with public safety and environmental quality are motivating regulation of gas development activity, even in places that have historical experience with the economic benefits of energy development.[20]

Stakeholder communities are concerned with the implications of shale gas development for water quality and air quality. In addition, stakeholders also cite concern with other 'quality of life' issues, such as noise and roadway traffic associated with energy development.

A recent study by Resources for the Future summarizes results of a survey of shale gas development regulatory activity in 27 states.[21] The study authors grouped shale gas well development regulations into 25 categories corresponding to 'elements' of the drilling and production process. Their analysis indicates that, on average, surveyed states regulate 16 of 25 development elements evaluated in the study. One or more regulations may apply within each development process element. And in addition to those state regulations, federal regulations may also apply to those same or other production process elements.

A recent query of the Advanced Energy Legislation Tracker suggests additional regulation on the horizon.[22] As of mid-year 2013, 38 states are debating new legislation of shale gas development activity. In total, 211 bills are currently under consideration at the state level. If passed, each of these laws is likely to require a state-level agency to promulgate one or more regulations to ensure implementation of new legislation.

Policymakers in these states are challenged with balancing the benefits and costs of proposed legislation. Due to the oftentimes-unique objective of each regulatory initiative, the benefit calculus may differ from proposal to proposal. The opportunity costs, however, are not dissimilar. To the extent that these regulations increase the cost of development or prohibit shale gas well development outright, then a significant part of the opportunity cost of

[19] E.g. the Marcellus development in New York and Pennsylvania.
[20] For example, see Linehan and Stefan, "Global List of Fracking Bans and Moratorium(sic)".
[21] Richardson 2013.
[22] Per query of all pending natural gas development legislation at the state level, on Sunday, June 30, 2013.

regulation is the economic benefits of the wells not drilled. And based on a nearly 10 year history of shale gas development in the U.S., policy makers now have the information necessary to estimate the basic opportunity costs of shale gas regulation.

IV. A tale of two states: Assessing the Marcellus in Pennsylvania and in New York

The Marcellus Shale represents an interesting case for evaluating the costs of state regulation of energy development. Appalachia was the location of the first commercial petroleum well drilled in the U.S. In 1859, Colonel Edwin Drake drilled the 70-foot well outside of Titusville, Pennsylvania.[23] Over the century that followed, the region was host to a sometimes-vibrant energy sector. By the mid-1980's, and after a number of failed attempts by OPEC to engineer higher oil prices, the industry largely abandoned the region for the relatively large plays in the American Southwest, the Gulf of Mexico, and Alaska.

By the mid-2000's, however, smaller 'independent' domestic oil and gas producers were improving and refocusing relatively familiar technologies on shale gas plays across the U.S. In particular, Mitchell Energy & Development is widely credited with proving, over the preceding decade or more, that a combination of directional drilling and hydraulic fracturing could be used together to unlock the vast potential of natural gas locked in the Barnett shale.[24]

Later that decade, Terry Engelder from Penn State and Gary Lash from SUNY – Fredonia provided an early but important calculation of natural gas in place in the Marcellus formation. The resource spans roughly 50 million acres, across six states in the Appalachian region. The geoscientists estimated that roughly 500 TCF was trapped, mostly in Pennsylvania, West Virginia, New York, and Ohio.[25]

Since then, improvements in directional drilling and hydraulic fracturing have reduced the cost of recovering gas from tight shale reservoirs. Well-known, major international energy producers have joined smaller independents in developing the largest shale gas deposits, such as the Marcellus. And this dynamic mix of players has brought economic benefits to a broad range of stakeholders.

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[23] Anderson, 1984.
[24] Fowler 2009.
[25] Engelder and Lash 2008 provide an early estimate of total gas in place, not an estimate of recoverable reserves.

Pennsylvania illustrates the magnitude of the economic benefits that can flow from the Marcellus. In 2010, shale gas developers drilled nearly 1,600 wells.[26] These wells were the result of $7.4 billion of investment that year.[27] In addition, the industry spent another $2.1 billion on lease acquisitions and bonus payments, and $1.3 billion on midstream infrastructure. Including spending on exploration and royalty payments, industry expenditures totaled $11.5 billion in 2010.[28]

Investment in the Marcellus in 2010 is estimated to have resulted in total value added of $11.1 billion in Pennsylvania.[29] The study authors estimate that industry activity supported 140,000 jobs, distributed across a broad range of industries.[30]

The estimation framework presented in the appendix of this report provides a conservative estimate of the opportunity cost of regulation – it only considers the economic impacts of cash flows associated with drilling and producing activities. Total proved reserves in the Marcellus were estimated at 13 TCF in 2010, up from 4.5 TCF in 2009, and 102 billion cubic feet (BCF) in 2008.[31] Proved reserves estimates are growing rapidly because the play is in the early stages of development. Consequently, technically recoverable reserves may be a better predictor of ultimately recoverable reserves. Analysts estimate that the Marcellus contains technically recoverable reserves in the range of 141[32] TCF to 330 TCF.[33]

Pennsylvania is only one of six states with a Marcellus endowment. Table 2 summarizes the approximate distribution of the Marcellus shale gas play.[34] If reserves are proportional to the distribution of acreage, Pennsylvania producers may ultimately recover 49 TCF to 116 TCF. Assuming each well ultimately recovers 1.8 BCF, Pennsylvania would require between 27,000 and 64,000 wells to produce all technically recoverable reserves.[35]

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[26] Based on data from the Pennsylvania Department of Environmental Protection as summarized by Kelso 2012, Fractracker.org.
[27] Considine et al. 2011. Note, this expenditure suggests an average well cost of $4.68 million, based on well count from previous footnote.
[28] Ibid, table 2.
[29] Ibid, table 4.
[30] Ibid, table 5.
[31] EIA 2012.
[32] EIA 2011.
[33] Levitt 2012.
[34] US EIA 2011.
[35] Laurenzi and Jersey predict estimated ultimate recoveries in the Marcellus will average 1.8 BCF.

Alternatively, Pennsylvania could require as few as 16,000 wells assuming a per-well estimated ultimate recovery of 3 BCF.[36]

Table 2

State Distribution of Marcellus Shale Play

(state)	(%)
Pennsylvania	35
West Virginia	21
New York	20
Ohio	18
Virginia	4
Maryland	1

Drilling in Pennsylvania rose to 1,937 wells in 2011.[37] And by mid-year 2012, drilling was expected to result in 2,200 wells, a pace considered sustainable by many analyses.[38] Assuming a rate of 2,000 wells per year, gross state product associated with well drilling and producing activities is estimated to total $7.3 billion in the third year of that pace of activity. This economic activity results in total wage payments of $5.9 billion, and supports nearly 73,000 jobs. Income after federal tax payments amount to over $4.2 billion.

A sustained level of drilling activity supports a commensurate level of jobs and economic output. At the same time, the number of jobs associated with producing operations from previously drilled wells continues to grow. As a result, a constant level of investment in the Marcellus is associated with economic growth over the period of investment. For example, in the fifth year of drilling at a pace of 2,000 wells per year, Marcellus drilling and producing activity is expected to drive $9.5 billion in gross state product and support 93,000 jobs. And after 10 years of investment at this pace, drilling and producing activities will generate over $12 billion and support over 123,000 jobs. This is equivalent to approximately 2.2% of current gross

[36] Many financial analysts predict per-well recoveries of 3 BCF; Laurenzi and Jersey estimate that 90% of Marcellus wells will ultimately recover more than 0.4 BCF, and 10% of Marcellus wells will ultimately recover more than 3.9 BCF.
[37] Kelso 2012.
[38] Detrow 2012. Or, by calculation of total potential number of wells in previous paragraph, drilling at this pace could be sustained for seven to 29 years.

state product,[39] and 2.1% of current state employment. Moreover, gross state product associated with well drilling and producing activities would be growing in excess of 4% per year.

Other Marcellus shale states have the opportunity to realize economic benefits commensurate with their resource endowments. New York, thus far, at least, has chosen a different path. In 2010, the state senate voted to impose a moratorium on hydraulic fracturing in New York.[40] And in 2012, the Governor declined to lift the moratorium.[41] The foregone economic benefits of undrilled wells represent a significant part of the costs of this decision.

New York's technically recoverable share of the Marcellus is estimated at 28 TCF to 66 TCF. Assuming 1.8 BCF per well, New York has the potential to develop 16,000 to 37,000 wells. Or assuming 3 BCF per well, New York may be host to at least 9,000 wells.

If New York were to permit drilling activity, the state could support five to 19 years of drilling at the same pace currently believed to be sustainable in Pennsylvania, 2,000 wells per year. At that pace of development, one could argue that New York would experience an economic impact as estimated in Considine et al. of $11.1 billion and 140,000 jobs.

Considering only the economic impacts of well drilling and producing cash flows excludes some economic activity attributable to energy development. However, this measure may be valued by economic policymakers for its simplicity and transparency. Assuming the same 2,000 well-per-year pace as currently anticipated in Pennsylvania, gross state product associated with well drilling and producing activities in New York is estimated to total $7.8 billion in the third year of that pace of activity. This economic activity results in total wage payments of $5.6 billion, and supports over 69,000 jobs. Income after federal tax payments would amount to over $4 billion.

Alternatively, one may argue that the pace of development is proportional to the magnitude of the resource. In this case, the total economic impact of the Marcellus in New York would be estimated at 57% of that in Pennsylvania, or $6.3 billion in value added and 80,000 jobs.[42]

[39] BEA 2012.
[40] Navarro 2010.
[41] Navarro 2012.
[42] I.e. 57% of the impact as estimated in Considine et al. 2011.

The more conservative impact estimate of well drilling and producing cash flows is also instructive. A well development pace of 1,140 per year would represent a pace of investment proportional to New York's Marcellus endowment. Within three years under this assumed pace of development, well drilling and producing cash flows would generate $4.5 billion of gross state product, and support a total of 39,000 jobs generating $2.3 billion of in-state wage payments, excluding federal taxes. In the fifth year of this development pace in New York, Marcellus drilling and producing activity is expected to drive $5.9 billion in gross state product and support 51,000 jobs, with $3 billion in income after federal taxes. And after ten years of investment at this pace, drilling and producing activities will generate over $8 billion and support nearly 69,000 jobs generating over $4 billion in wages after tax.

At the ten-year mark, gross state product associated with well drilling and producing operations would be growing at nearly 4.7% per year. These cash flows are equivalent to approximately 0.7% of current gross state product.[43] This conservative estimate of prospective job gains is equivalent to 0.9% of current employment in the state, or 11% of the unemployed workforce. These figures represent over three months of employment additions at New York's current rate of labor market performance.[44]

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[43] BEA 2012.
[44] New York State Department of Labor, 2013.

V. Conclusion

America's shale gas reserves represent a significant opportunity to a broad range of stakeholders. The relatively low carbon content of natural gas yields benefits for public health and the environment. And the abundance of the country's gas supplies promises to improve its energy security and reliability. Finally, well drilling and producing operations promise significant benefits.

Regulatory initiatives, however, hold potential to discourage development of a significant share of this energy resource. The nation's shale gas resource is relatively diffuse, in some cases near communities with little familiarity with energy activity. And even in states with more experience with the industry, the proximity of reserves to population centers has heightened concerns about industry practices.

Regulators who desire to balance the costs and benefits of regulation require a relatively transparent method to do so. This report shows how accounting for well drilling and producing cash flows can provide a transparent and conservative estimate of the cost of shale gas regulation. And because this estimate is incomplete, policy makers can confidently reject regulatory proposals whose benefits are not demonstrably larger than their minimum opportunity costs, defined by the economic benefits associated with discouraged well drilling and producing operations.

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Appendix I: Analytical Framework

This appendix describes an analytical framework that can be used estimate the economic benefits associated with drilling and producing a typical shale gas well. These economic benefits represent an important share of the total costs of shale gas regulation. And because the drilling and production process is relatively common across gas deposit basins, model assumptions can be varied to correspond to the geologic conditions that are representative of different shale gas plays. We model a typical Marcellus shale gas investment opportunity to illustrate application of the gas well drilling and producing cash flows framework. The model is highly stylized in order to be relatively transparent to the layman policymaker.

A. Description

A gas well drilling producing cash flows framework can be used to estimate the economic impact of a typical shale gas well. The analysis can be easily modified to account for differences in shale gas play depth, and hence investment costs. The analysis can also be easily modified to account for differences in well productivity, and hence revenue, and any other geologic or commercial parameter that the modeler believes is distinctive of the basin under consideration.

The analysis framework provides cash flows corresponding to those obtained using a conventional input-output model. However, whereas input-output models are typically formulated to account for all expenditures or income at an industry-wide level, the present analysis considers only particular activities within the oil and gas industry, namely those associated with well drilling and producing operations.

The framework accounts for direct and indirect expenditures necessary for well drilling and producing operations. 'Direct effects' generally refer to those initial expenditures by oil and gas development companies and the resulting activities of their employees and primary suppliers. 'Indirect effects' refer to the follow-on expenditures through subsequent levels of suppliers to drilling investment and producing activities.

Well drilling phase expenditures are capital intensive. Capital goods are acquired from primary suppliers of various tubular products and drill site services. Those primary suppliers, in turn, acquire labor and other goods and services in order to fabricate their goods for sale. This investment cash flows framework models four levels of suppliers in support of primary well drilling investment activity.[45]

Producing operations generate cash flows to a broad range of stakeholders. (see figure 2 and table 1.) Taxes on production revenue flow to a variety of stakeholders at the State and local level. Mineral royalty owners receive a fraction of revenue net of production taxes. Operating and administrative expenditures represent worker salaries, and goods and services purchased from suppliers. Indirect economic effects from producing operations include those expenditures and activities by subsequent suppliers of labor and services that support direct operating expenditures. The model estimates four levels of suppliers in support of direct oil and gas production activity.[46]

A supply chain cash flow model accounts for a broad set of stakeholders with commercial interests in well drilling and producing operations. In addition, the model provides a basis for approximating induced effects – those expenditures on goods and services that lie outside the well drill and production supply chain. Direct development and production expenditures, indirect expenditures through the supply chain, and those expenditures induced by incomes earned through direct and indirect activity all represent taxable bases, resulting in flows to stakeholders with interests in state and local public financial conditions.

In order to summarize the opportunity cost to states of foregone drilling and producing activity, this study utilizes a relatively conservative in-state measure of economic activity analogous to national income plus in-state tax receipts, net state income (NSI). NSI includes the largest share of gross state product, employee compensation, which includes earnings to workers at all stages of the supply chain, including those induced by direct and indirect employee wage expenditures. However, we exclude federal income tax payments because federal transfers into states are not necessarily proportional to federal tax payments. We also include proprietor income, corporate profits, rent, and interest income, net of federal taxes,

[45] The model has been estimated with as many as seven levels of support in the supply–chain. Those results were not materially different from the results reported below.
[46] See previous footnote.

earned by in-state residents from in-state well drilling and producing activity. Finally, we include local and state production taxes, as these receipts presumably flow to in-state stakeholders.

NSI intentionally understates the total value associated with well drilling and producing activities in order to provide a measure relevant to in-state policymakers. A measure analogous to gross domestic product would be the measure of interest to a hypothetical social planner charged with balancing the costs and benefits of prospective regulation. For example, a measure of the total value of well drilling and producing activities would include the value of paid taxes (value not flowing to a factor of production) and the value of capital consumed in the development and production process (depreciation.) In practice, however, real policymakers are understandably interested in comparing the net benefits and costs to their constituents.

As a matter of convenience, NSI understates the net in-state benefits associated with well drilling and producing operations. For example, the analysis does not include expenditures for investment in a pipeline network that may be necessitated by regional energy development. The analysis also does not include in-state benefits associated with lower natural gas prices. And the analysis does not include the value of environmental quality or energy reliability and security associated with greater utilization of domestic natural gas and accruing to in-state residents. Thus, the measure of foregone value presented here can be considered a conservative estimate of the maximum potential value to in-state stakeholders associated with in-state well drilling and producing activities.

B. Assumptions

The well drilling and producing cash flows framework is based on a number of assumptions that may be varied to reflect the geologic and economic conditions of specific shale gas plays. The assumptions utilized in the present analysis are selected conservatively, in order to provide a lower estimate of the economic impact from well drilling and producing operations in the Marcellus.

- Initial investment expenditures for well drilling and equipment are based on play or basin-specific averages. For example, wells in the Marcellus are estimated to average $400 per linear foot of well depth.[47] All capital investment expenditures are modeled at 10% labor / 90% goods and services.
- Direct capital goods expenditures are modeled at 10% labor / 90% goods and services. Suppliers of capital goods are modeled at 20% labor / 80% goods and services. Both direct and supplied capital goods labor and goods and services are modeled as sourced 40% in-state resident / 60% out-state resident.

Table A1

Time period year	Initial production rate (MCFPD)	Fractional decline
1	4,000	0.75
2	1,000	0.35
3	650	0.22
4	507	0.17
5	421	0.13
6	366	0.11
7	326	0.09
8	297	0.08
9	273	0.07
10	254	0.06

- Production is modeled at flow rates and declines typical for the basin of analysis.[48] For example, in the Marcellus, initial rates of production assumed to average 4,000 mcfpd. That rate of production is assumed to decline as illustrated in table A-1. For years 11 to 30, wells are modeled to decline at an exponential rate corresponding to the fractional decline anticipated in year 10.
- Liquid to gas ratios are modeled at 10 bbl/MCF, and based on aggregate production history in recent years. This value may underestimate the current liquid to gas ratio as developers have shifted to more liquid-rich targets.
- Revenues are modeled at $4 per MCF and $90 per bbl based on recent pricing in futures markets.

[47] US EIA 2011.
[48] Ibid.

- Severance taxes and local property taxes are modeled at rates representative of the basin under consideration. For example, Pennsylvania does not have a severance tax, but levies a local impact fee of $50,000.[49] Other states may charge some share of production severance tax.[50]
- Mineral royalties are modeled at an average rate of 16.7%.[51] Mineral royalty recipients are modeled as 70% in-state resident / 30% out-state resident.[52] Mineral royalty income recipients are expected to spend 5% of this income and save or invest the remaining 95%.[53]
- Total production expenses are modeled at $2.00 per MCF. Leasehold production costs are modeled at $1.40 per MCF,[54] SG&A is modeled at $0.20 per MCF. Both leasehold and SG&A are modeled at 67% labor / 33% goods and services. The remaining $0.40 per MCF are other services, which are modeled at 33% labor / 67% goods and services. Field production costs are modeled at 80% in-state resident / 20% out-state resident; SG&A and other production costs are modeled at 60% in-state resident / 40% out-state resident.
- Employment is estimated based on costs that decline with the level of expenditures. For example, workers employed at the direct expenditures level are assumed to receive $100,000 per fully loaded employed position. Workers at the first through fourth levels of supply are modeled to $75,000, $65,000, $60,000, and $55,000, respectively.[55]
- Federal corporate income taxes are modeled at 15%, federal personal taxes are modeled at 28%. State tax rates are modeled corresponding to the state under analysis.[56]

[49] see http://stateimpact.npr.org/pennsylvania/tag/impact-fee/.
[50] Nationwide, Chakravorty et al. 2010 estimate effective severance tax rates range from negligible in California to 12% in Alaska. In addition, many municipalities assess taxes on the value of oil and gas produced property. In Colorado, for example, the state levies a 5% production tax, and local municipalities levy property taxes typically in the range of 4% to 15%.
[51] One sixth not an uncommon royalty rate. In the present analysis, this fraction amounts to approximately $2.4 million in royalty payments over the live of a typical Marcellus well, as compared to $2.5 million reported in Kelsey and Murphy, 2011.
[52] A 2012 examination by the author of payment records to royalty recipients by a sample of Colorado companies indicated that 80% of royalty payments were paid to in-state recipients. The assumption used in this study is chosen to provide a conservative estimate of in-state economic impacts.
[53] Kinnaman 2010 citing Scott 2009. In the interest of conservatism, the present analysis assumes no economic impact from the 95% of royalty receipts saved or invested each year.
[54] Baihly et al. 2011, Table 2.
[55] Wobbekind et al. 2011, p. 19, table 19 suggests average total costs for oil and gas industry workers in Colorado are $72,000.
[56] For example, personal income is taxed at a rate of 3.07% in Pennsylvania (see http://www.portal.state.pa.us/portal/server.pt/community/personal_income_tax/11409), and at a marginal tax rate of 6.65% in New York (marginal rate for incomes above $77,150 filing singly, $154,350 filing jointly, see http://taxfoundation.org/article_ns/state-individual-income-tax-rates-2000-2013). Corporate income is taxed at a rate of 9.99% in Pennsylvania, and 7.1 % in New York (see http://www.taxpolicycenter.org/taxfacts/Content/PDF/state_corporate_income.pdf).

C. Results

Table A-2 summarizes the gross state product, gross employment income (which represents the majority of gross state product), and employment associated with the cash flows from the initial investment period and first 5 years of producing life of a typical Marcellus shale gas well drilled in Pennsylvania. In the initial investment year, year 0, well drilling activity results in approximately 10 in-state employed positions and nearly 30 out-state employed positions. These jobs are associated with over $2.6 million in worker wages. Worker wages account for nearly all in-state gross state product in this drilling phase. Out-state worker wages exceed outstate gross state product due to predominantly negative corporate cash flows in the early investment phase, which disproportionately flow to out-state equity holders.

Table A-2 – GSP and Gross Wages for Typical Pennsylvania Shale Gas Well

		---------------- Stakeholder Value at Risk ----------------				
year	in-state GSP* ($000)	in-state employment income ($000)	in-state employment positions (#)	out-state GSP* ($000)	out-state employment income ($000)	out-state employment positions (#)
0	730	715	9.5	1,892	1,904	28.1
1	2,098	1,583	19.2	972	581	7.3
2	831	638	7.8	401	231	2.9
3	592	454	5.5	287	164	2.1
4	476	366	4.4	231	132	1.7
5	405	311	3.8	197	112	1.4
note: * excludes depreciation						

In the production phase, years 1 and thereafter, employment and worker earnings shift to predominantly in-state because a greater share of production activities are assumed to be sourced in-state. Each well supports a total of nearly 27 jobs in the first year of production, with the job support of each well declining in later years as lower production necessitates less attention by all levels of production personnel.

Table A-3 summarizes the net state income, the net share of benefits associated with well drilling and producing operations that accrue to in-state stakeholders. These values exclude federal tax payments paid on employment and business income, but include state severance taxes. Policymakers may prefer to consider net benefits to in-state stakeholders as a measure of the opportunity cost of prospective regulation.

Table A-3 – Net State Income and AT Wages for Typical Pennsylvania Shale Gas Well

		---------------- Stakeholder Value at Risk ----------------				
		in-state	in-state		out-state	out-state
	in-state	employment	employment	out-state	employment	employment
	NSI	income AT	positions	NSI	income AT	positions
year	($000)	($000)	(#)	($000)	($000)	(#)
0	526	515	9.5	1,364	1,371	28.1
1	1,525	1,140	19.2	700	418	7.3
2	598	459	7.8	289	166	2.9
3	426	327	5.5	206	118	2.1
4	343	263	4.4	166	95	1.7
5	292	224	3.8	142	81	1.4

Policymakers can utilize these estimates as a point of comparison to the prospective benefits of proposed regulation. Policymakers can combine the magnitude (number of wells) and timing of well development activity discouraged by regulation. This estimate of the direct, indirect, and induced economic activity attributable to a regulatory proposal should be considered as an important part of the opportunity costs associated with the prospective benefits of a particular regulatory proposal.