A Note on Oil and Gas Production from Shale and Long-Run U.S. Economic Growth

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Summary

The short-term economic benefits of oil and gas production from shale for the U.S. economy have been widely discussed, but the long-term effects remain unclear. These long-run impacts likely depend upon the degree to which such oil and gas production can impact growth in capital per worker or technological progress throughout the economy. Oil or gas production from shale can lead to economic growth through economy-wide increases in capital per worker directly through investment in the oil and gas extraction sector and along the supply chain. Alternatively, the availability of low cost natural gas in large quantities may lead to replacement or additions to capital stock outside of oil and gas extraction and related industries.

Oil and gas production can lead to economy-wide technology gains directly through the application of technologies used in extraction and related activities in other sectors. There is much greater upside and uncertainty, however, surrounding if such production can lead to technological growth in other sectors indirectly. Are there currently important and productive technologies not being used or applied that become plausible because of lower-cost natural gas? Will there be transformative technologies developed for use with lower-cost natural gas that currently do not exist? And might each of these individually lead to other technologies that currently do not exist?

Introduction

There are various ways in which the natural gas market can impact U.S. economic activity in the short-run.[1] Generally, they can be summarized as working initially through either the supply or demand sides of the economy. The most straightforward supply impact is that changes in the production of natural gas vary output in the oil and gas extraction sector, as well as associated industries. This direct change in production and its ripple through the oil and gas supply chain have been the focus of most recent analysis on the economic impact of oil and gas production for the U.S. Natural gas also influences economic activity on the supply-side of the economy through the investment of firms. The application of hydraulic fracturing and horizontal drilling has made a very large resource base available. This potential supply has led to substantial investment in the oil and gas extraction and mining support sectors, as well as other related industries.

Lower natural gas prices, irrespective of their cause, lower input costs for firms. These can be passed on to consumers by allowing firms to supply the same amount of goods and services at lower prices. Firms may also realize higher profits, which can lead to additional hiring, capital investment, higher dividends, or saving. Each has a follow-on impact on the economy-wide demand for goods and services. Lower prices also directly influence demand through consumers. They can raise disposable income, lower precautionary savings (or raise it in the case of a price rise), or cause consumers to change their plans for the purchases of durable goods.

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[1] For more on these see Vipin Arora and Jozef Lieskovsky, "Natural Gas and U.S. Economic Activity," *The Energy Journal*, Forthcoming.

Each of these result in alterations to the economy-wide demand for other goods and services stemming from the initial variation in the price of natural gas.

It remains unclear, however, if and how these channels might carry over to influence long-run U.S. economic growth. Standard economic theory suggests that growth in income per person in the long-run comes from a variety of factors, including increases in capital per worker (capital deepening), growth in total factor productivity, and improvements in labor quality.[2] See Appendix 1 for a derivation of this relationship. There may also be a long-run trade effects due to oil and gas production.

The Impacts on Capital Deepening

Capital deepening is a process by which available capital per worker, or capital per hour worked, increases. This occurs when the growth rate in the capital stock is larger than the growth rate in hours worked. Capital widening is a related process whereby the capital stock and hours worked grow at similar levels. In this case capital per worker is not necessarily growing, but the aggregate capital stock is rising. It is capital deepening that is generally associated with gains in income per person.

How could oil or gas production lead to economy-wide increases in capital per worker? One way is directly through investment in the oil and gas extraction sector and along the supply chain. Alternatively, the availability of low cost natural gas in large quantities may lead to replacement or additions to capital stock outside of oil and gas extraction and related industries.

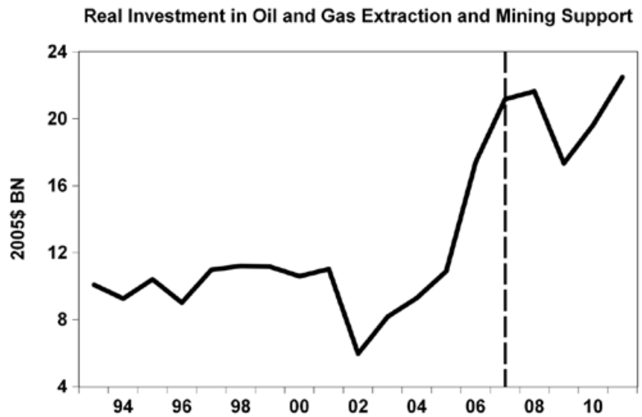
Data from the Bureau of Economic Analysis (BEA) clearly show greater investment in the oil and gas extraction sector since 2002 (see Figure 1). Related analysis from the Bureau of Labor Statistics (BLS) shows that support activities for mining was one of the largest contributors to output growth from 1998-2010.[3] But even with the large increases in investment, the oil and gas extraction sector was a negative contributor to output growth over this period. This has likely reversed due to the recent investment, but the magnitude of such direct impacts on economy-wide growth remains uncertain.

Even if one considers investment in oil extraction due to shale, money which may otherwise have been spent overseas, the potential size of total investment in these and related sectors is small on an economy-wide basis. Therefore, it is unlikely that direct investment and subsequent growth in the capital stock in oil and gas extraction and related sectors will contribute more than a small amount to economy-wide growth.

[2] A common criticism is that these factors are themselves the outcome of many economic interactions and outcomes that remain unexplained.

[3] See Chart 1 in Susan Fleck, Steven Rosenthal, Matthew Russell, Erich H. Strassner, and Lisa Usher, "A Prototype BEA/BLS Industry-Level Production Account for the United States," mimeo, 2012.

Figure 1



There is much greater potential for gains in income per capita due to capital deepening in the rest of the economy that might follow from the low-cost and abundance of natural gas. Possible examples include the construction of new manufacturing plants close to natural gas supplies, the building of new electric power generation plants to use cheap natural gas, and investment or retrofitting of car assembly plants to build natural gas fueled vehicles, to name a few.

The magnitude of economic gains from these and related examples depend upon two factors: displacement versus additions and the productivity of the new capital stock versus what it replaced. If investment that stems from oil and gas production is used to replace older capital stock, for example with retrofits of older factories or displacement of gasoline-powered vehicles, there is not necessarily an increase in capital per worker throughout the economy. There is an increase in the effective capital per worker in these cases, however, when the newer factories and machines are more productive than older ones, possibly because of better technologies.

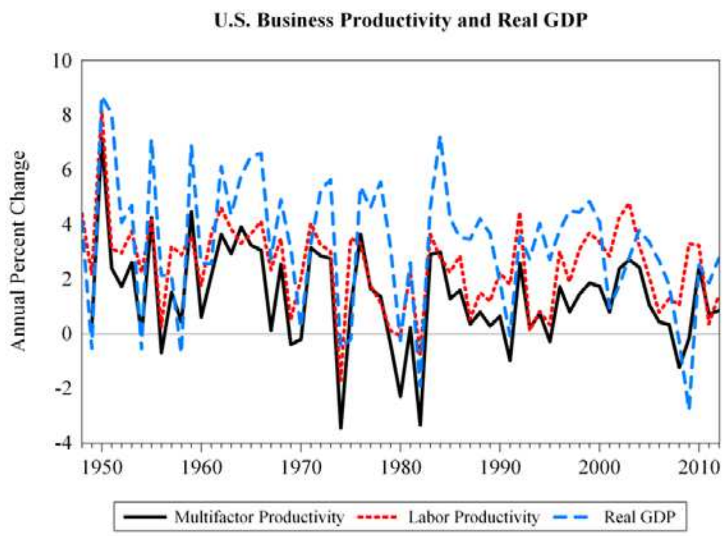
Unlike with direct investment, it is very difficult to predict how greater oil and gas production will affect capital deepening in the aggregate economy. If there are few additions to the capital stock relative to replacements, then any growth in income per person through this channel due to shale will likely remain small. But if additions to the capital stock due to shale are large across the economy, if there actually is a manufacturing renaissance led by cheap natural gas, then gains could be quite large. And these additions to the capital stock may depend upon technologies that are available but unused, or which have yet to be discovered.

<u>The Impacts of Shale on Total Factor Productivity</u>

Total factor productivity, also called multifactor productivity, relates total output to a combination of inputs used in the production of that output. Conceptually, it is the efficiency of the production process. It is measured implicitly, by computing changes in output that cannot be accounted for by changes in combined inputs. These inputs include factors of production such as labor and capital, as well as intermediate goods and energy.[4] Total factor productivity growth is often thought of as technological progress, but also includes general knowledge, organizational structures, and management techniques, among others.[5]

Figure 2 shows the growth rates of U.S. multifactor and labor productivity and real GDP since 1948 from the BLS and the BEA.

Figure 2



While these series do not move perfectly together, there is a clear correlation between GDP and productivity growth. And the growth rate of total factor productivity (and labor productivity) has a strong relationship with the growth rate of real U.S. GDP in the medium-to-long term.[6]

The biggest potential gains in growth per capita from oil and gas production, and the most uncertain, are from technological progress. How could the ability to extract oil and gas from shale lead to growth in technology? Again, there is a direct channel and an indirect channel. The direct channel, often referred to as embodied spillovers, is by the use of methods and technologies that have been implemented in the exploration, extraction, and delivery of shale oil and shale gas to other areas. An example of this is the advanced seismic techniques that are involved in the extraction process. Although beneficial to the economy, it is likely that direct application of these technologies will be a small contributor to economic growth. Figure 3 shows the growth rate of multifactor productivity in the petroleum and coal products sector (data on oil and gas extraction is unavailable from the BLS). There has been some total factor

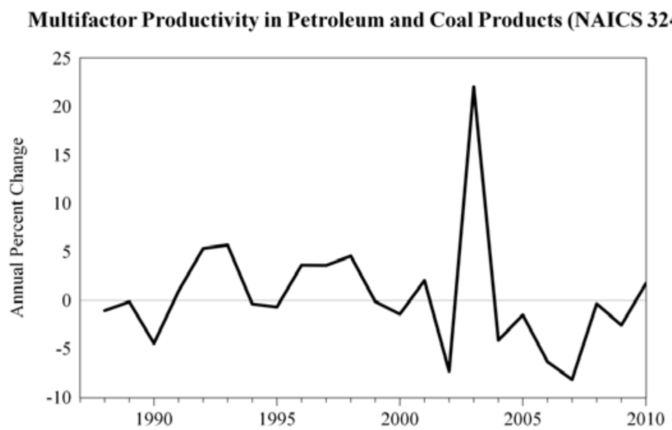
[4] Labor productivity relates total production to hours worked throughout the economy. It is measured as the ratio of the output of goods and services to the labor hours devoted in production of those goods and services.

[5] See Robert Shackleton, "Total Factor Productivity Growth in Historical Perspective," U.S. Congressional Budget Office Working Paper 2013-01, March 2013, for more on U.S. TFP growth since 1870.

[6] For more on this see Charles Steindel and Kevin J. Stiroh, "Productivity: What is it and Why Do We Care About it?" Federal Reserve Bank of New York Staff Report 122, 2001.

productivity growth here, but certainly not enough, given the size of this and related sectors, to drive overall economic growth substantially higher.

Figure 3



There is much greater upside and uncertainty surrounding if, how, and when oil and gas production can lead to technological growth in other sectors indirectly through disembodied spillovers. Are there currently important and productive technologies not being used or applied that become plausible because of lower-cost natural gas? Will there be transformative technologies developed for use with lower-cost natural gas that currently do not exist? And might each of these individually lead to other technologies that currently do not exist or are unused?

There are no clear answers to any of these questions. But the main point is that there is a potentially large upside to oil and gas production in terms of economy-wide productivity, and therefore long-run gains in income per person. The question remains the plausibility of such an upside.

The Impacts of Shale on Labor Quality and Trade

Improvements in the skills of workers are another factor that can also result in longer-term economic growth. Oil and gas production can lead to improvements in worker skills, primarily through on-the-job training (often called learning by doing), although the economy-wide impact of these improvements is likely to be small. Such improvements will occur in the oil and gas extraction sector and along the supply chain. Any associated capital deepening or technological progress, however, will also likely lead to a more skilled workforce in the impacted sectors.

Because natural gas and oil are both tradable goods there are potential long-run benefits to the U.S. economy from the removal of export barriers.[7] Standard trade theory suggests that the removal of export restraints can be welfare improving when the impacts on global prices are not too large. There may also be so-called terms of trade effects associated with oil and gas

[7] Exporting natural gas currently requires approval from the U.S. Department of Energy (DOE).

production if exports are allowed. In this case changes in the relative prices of U.S. exports versus imports can impact domestic income. It is unclear, however, whether these terms of trade effects will be beneficial for the U.S. economy. With either trade channel it seems the implications for long-run U.S. economic growth are not large, as trade in natural gas or oil is likely to be a small fraction of total U.S. exports.

Appendix 1: Factors Driving Growth in Income per Capita

Consider economy-wide output (y) as a function of the total capital stock (k), a measure of total labor input (l), and total factor productivity (a), where the lower-cases indicate the variables are in natural logs:[8]

$$y = aF(k, l)$$

The capital stock and labor input can both be differentiated into specific types of capital and labor input. In the case of capital this can be different types of machines, buildings, and the like:

$$k = K(k_1, k_2, \dots, k_n)$$

Labor input depends upon hours worked [h] by types of worker based on their skill, education, age, or other factors:

$$l = L(h_1, h_2, \dots, h_n)$$

In the shorter-term aggregate output also depends upon how intensely capital and labor are used. To incorporate this concept define [c] as the utilization rate of capital and [e] as worker effort. The initial production technology is then written as:

$$y = aF(c * K[k_1, k_2, \dots, k_n], e * L[h_1, h_2, \dots, h_n])$$

To put this expression in terms of income per hour worked, assume the production technology has constant returns to scale (doubling inputs leads to a doubling of output) and that firms maximize profits (or minimize costs). This equation is then logarithmically differentiated (where hats represent log changes) to give:

$$\hat{y} = \hat{a} + \alpha[\hat{k} + \hat{c}] + (1 - \alpha)[\hat{l} + \hat{e}]$$

Take α as a parameter which represents the share of income in the economy that is paid to owners of capital. Next, define utilization of both capital and labor as:

$$\hat{u} = \alpha\hat{c} + (1 - \alpha)\hat{e}$$

And then introduce labor quality to capture the benefits of changing the composition of hours:

$$\hat{q} = \hat{l} - \hat{h}$$

Here, $\hat{h}$ are total hours worked in the economy. The growth rate of value-added is then defined as:

$$\hat{y} = \hat{a} + \alpha\hat{k} + (1 - \alpha)[\hat{h} + \hat{q}] + \hat{u}$$

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[8] For a full derivation see John Fernald, "Productivity and Potential Output Before, During, and After the Great Recession," Federal Reserve Bank of San Francisco Working Paper 2012-18, 2012.

Finally, income per capita (income per hours worked) is derived by subtracting the growth rate of total hours worked from both sides to give:

$$\hat{y} - \hat{h} = \hat{a} + \alpha\left[\hat{k} - \hat{h}\right] + (1 - \alpha)\hat{q} + \hat{u}$$

This expression shows the driving factors behind income per capita growth in the long-run: total factor productivity growth [$\hat{a}$]; changes in capital per worker$\left[\hat{k} - \hat{h}\right]$; the quality of workers [$\hat{q}$]; and utilization rates of capital and/or labor [$\hat{u}$].