The Death of Resource Constraints

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As is almost always the case, a quote from an Englishman offers the best and pithiest summary of the current energy situation. Often that person is Winston Churchill. In this instance, though, it is John Maynard Keynes, the economist despised by so many American neoconservatives. Keynes wrote this in 1937:

> …the idea of the future being different from the present is so repugnant to our conventional modes of thought and behavior that we, most of us, offer great resistance to acting on it in practice.[1]

This quote appears at the start of a December 2012 report on global trends by the National Intelligence Council (NIC), part of the Office of the Director of National Intelligence.[2] Most of the authors work or consult for NIC.

I use the quote here in the context of resource economics. For more than forty years, US policymakers, economists, academics, business people, and almost all individuals have planned and acted believing oil and gas resources were scarce. Americans were not alone. The elites and ordinary citizens of nearly every country in Asia, Europe, Africa, Oceania, and the Americas have thought, deliberated, and acted in similar fashion. Officials in many advanced economies have pushed aggressively to reduce oil and gas use. Initially, they did this to preserve hard

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[1] See John Maynard Keynes, “Some Economic Consequences of a Declining Population,” *Eugenics Review* 29, April 1937, pp. 13-17 [http://goo.gl/MZXXN].
[2] See *Global Trends 2030: Alternative Worlds,* December 2012 [http://goo.gl/rx9fr].

currency and limit financial transfers to oil and gas-exporting countries. More recently, such efforts have intensified as concern over global warming rises.

In contrast, countries blessed with large oil and gas reserves have worked in concert to raise prices for the last forty years. Many of these nations see oil and gas as their "currency" to modernize. Dubai, for example, has built on a grand scale. Others, such as Norway, have carefully controlled expenditures, setting aside income for the future when reserves are exhausted or possibly for when prices decline.

Consumers in many countries have seen economic growth slowed by high prices as factories closed and economic activity decreased. Their economic welfare has been cut as they have had to allocate greater portions of their income to pay for energy. Critics of energy use have often labeled such payments as "tribute" or "blackmail."

The situation will be very different by 2020. Although an idea repugnant *to conventional thinking*, technology developments will likely banish the resource constraint. These advances will drive the cost of tapping unconventional oil and gas reserves down to where it will be uneconomic to produce from many high-cost areas. The explosive production of these resources will probably take average oil and gas prices down over time, creating serious political dislocations in nations that operate expecting ever-rising prices. Companies planning long-term growth around high prices will also suffer the consequences of their bad decisions.

The transition from a world that believes oil and gas resources are constrained to one where there is essentially no limit will occur quickly in practice if not in thought. Wider and wider application of new technologies almost guarantees a surge in production. The resulting incremental supplies will put intensive downward pressure on prices. The fall will not be smooth, though. Countries and perhaps firms invested in high-cost reserves will do their best to sustain high prices. Their efforts will be supported by the consequences of socioeconomic dislocations in countries dependent on high and rising oil prices.

The transition will meet opposition from elites, especially government officials, politicians, companies invested in high-cost technologies, and, of course, organizations working to limit greenhouse gas emissions. Those seeking to build wind power facilities and solar power plants and to convince individuals to live "off the grid" will fight the widespread proliferation of cheap oil and gas. As Keynes warned, all these individuals will aggressively resist *acting in practice*. For many, the end of the resource constraint will be very bad news. Naturally, they will do everything possible to maintain the status quo.

Here I examine the unexpected, amazing dismantling of the resource constraint. The analysis begins by describing developments that make all existing projections of future oil and gas price trends irrelevant. In the past, the seeming resource limitations guaranteed that incremental costs and competitive prices would rise inexorably. In the future, incremental costs will follow drilling activity. The greater the activity, the lower the costs. Section I's title, "Drill Baby Drill to Drive Prices to Zero," derives from former Alaska governor Sarah Palin's signature catchphrase from the 2008 Republican National Convention. Little did she know then what import it would come to have.

The new *and repugnant to conventional thinking* world will require an entirely different approach to national resource management. Today, the United States prohibits crude oil exports. In addition, many here oppose exporting natural gas despite the fact that the US has an enormous competitive advantage regarding the fuel. The opposition comes primarily from those operating under the resource constraint model. In other words, they still believe we have finite reserves of oil and gas. These opponents of exports seek wrongly to have the US act as a mercantilistic nation, that is, they want to maximize the value-added from resources by selling only the finished goods produced from them.

Here I argue that the transition from a world facing constrained oil and gas reserves to one without constraints will occur under a regime where the United States seeks to export all hydrocarbons aggressively. A strong pro-export policy will create the maximum incentive to drill for oil and gas here. Such an export strategy will attract large inflows of foreign direct investment that will accelerate drilling and production programs. This activity in turn will drive down costs under current circumstances. The NIC calculates these costs will be $44 to $68 per barrel in 2020. These estimates are guesses. The likely costs will be half those figures or lower if drilling programs continue at the present rate. However, such continuation will require the relaxation of export limits. Here also, I revert to the thinking of a long-dead economist, Adam Smith. Smith argued that removing trade restrictions benefits consumers. In today's world, free trade in energy will hasten the transition to a global state of unconstrained resources. I discuss this issue in Section II, "Implications of Promoting Oil and Gas Exports."

The death of the energy constraint will also bring trouble to the world. The availability of low-cost oil and gas from the United States and other countries will put increasing pressure on prices, most likely causing serious political instability in energy-exporting nations such as Russia and potentially marginalizing major oil companies. At the same time, success in driving down oil and gas development costs, as well as the potential production surges in countries previously reliant on imports, will complicate efforts to address global warming. Nations that have shale resources will likely develop them regardless of the emissions impacts. Seeing a chance to stop paying "tribute" to energy exporters and to boost economic growth, they will aggressively pursue these opportunities.

The paper's third section, "Opening Pandora's Box," examines the consequence of technical change. I cannot conclude that the benefits associated with "The Death of Resource Constraints," this paper's title, are worth the cost. I do conclude, though, that the death is almost certain.

I. Drill, Baby, Drill – to Drive Prices to Zero

Oil prices have held the global economy hostage for almost forty years. In fact, the fortieth anniversary of the first oil shock will occur – but not be celebrated – in December 2013. At the time of the shock, 1973, crude prices went from \$3 per barrel to as high as \$15.

Today, that increase seems absurdly small. Forty years ago, though, it stunned the global economy. Following the event, business executives, government officials, planners, and economists scrambled to understand what had just transpired. The world soon learned that higher oil prices could have serious negative impacts on economic activity. Economic growth slowed, unemployment rose, and consumers discovered that petroleum supplies were not always assured.

The price increases spawned a new field of study: energy economics. Numerous learned papers came out that discussed the linkage between economic activity and oil. The price rise also prompted new government activities focused on the energy sector. Officials quickly began searching for ways to change consumer habits, promote conservation, boost domestic oil production, and shift consumption to other fuels like coal to reduce pressure on the global oil market.

These activities intensified over the following forty years. Periodic price increases reminded government officials, planners, and consumers that oil continued to hold the global economy for ransom. More recently, efforts to cut consumption of oil and all hydrocarbons have redoubled as concerns regarding global warming strengthen.

Despite these efforts, oil remains the greatest worry of many. Geologists, engineers, and scholars have all warned that petroleum resources are diminishing. Worse, various authors have repeatedly asserted that the world's largest oil reserves have been discovered and are being depleted. Again and again, they tell the public that oil production will peak and must inevitably decline. This "peak oil theory" probably reached the zenith of its popularity with the publication of Matthew Simmons' *Twilight in the Desert*.[3] In his book, Simmons chronicled the decreasing size of new oil discoveries. He warned that global supplies would inevitably drop, especially as output from the world's largest oil reserve, Saudi Arabia's giant Ghawar field, began to fall off.

Recently, Jeff Rubin asserted that the US economy was doomed to a no-growth future in his book *The Big Flatline*.[4] Rubin, like Simmons before him, sees nothing but higher oil prices ahead. Higher oil demand from an increasingly wealthy and fast-growing China would force prices up and up. One can almost hear Rubin, a Canadian, chortling as he pronounces that the steadily rising prices would strangle US economic growth. In his view, the economies of

[3] See Matthew R. Simmons, *Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy* (Hoboken, NJ: John Wiley & Sons, 2005).
[4] See Jeff Rubin, *The Big Flatline: Oil and the No-Growth Economy* (New York: Palgrave Macmillan, 2012).

resource-rich countries such as Canada and relatively debt-free nations like China would expand rapidly while indebted, oil-importing ones like the United States stagnated.

Ten or fifteen years from now, young economists and historians will inquire, “What was all that about?” Students will ask their teachers, “Why were policymakers so concerned about energy?” Economics graduate students will wonder why anyone would worry over an oil price change affecting economic activity.

By 2028 or 2030 at the latest, oil or natural gas prices will likely cease to be an issue for policymakers. Instead, their greatest focus will be global warming and perhaps political instability in nations that enjoyed great wealth from oil and gas production between 1973 and 2023.

Another major anxiety will be the economic state of countries, regions, and companies that aggressively pursued renewable energy sources such as wind, solar, hydro, and nuclear power. These entities will increasingly find themselves at a competitive disadvantage to those that rely on inexpensive natural gas and oil. Germany, for example, may find its industries facing the same predicament that English manufacturers faced in the late 1950s and early 1960s when US competitors using lower-cost energy could underprice them.

This dramatic transformation will occur because technological innovation has opened vast crude oil and natural gas reserves to development. These reserves, trapped in shale rocks, have been well known to geologists. The American Association of Geologists (AAG), for example, reported very large “possible reserves” many years ago. However, such resources were not counted as proven—the category cited by writers like Simmons and Rubin and the one most economists understand—because they could not be produced economically until 2011 or 2012.

Today, shale reserves, which were unprofitable to tap in the past, are today easily producible. Some put production costs at as little as $50 per barrel for oil and less than $3 per mcf for natural gas. These costs are falling thanks to technological advances. Oil and gas production, previously a complicated procedure involving huge expenditures to find traditional reserves trapped in reservoirs, has become a "manufacturing" process like assembling cars or airplanes. The experience of such processes suggests oil production costs will decline over time.

Here I lay out the implications of technological innovation that could reshape the global oil and gas industry. The section's title might well have been "Coping with Abundance."

The National Intelligence Council has captured the revolution's magnitude. Every four years, NIC publishes a study that outlines global issues and threats that could confront the nation and world over the next twenty years. In its *Global Trends 2030: Alternative Worlds*, the Council warns that surging US oil production could threaten global security. The authors put their case boldly:

> The prospect of significantly lower energy prices will have a significant positive ripple effect for the US economy, encouraging companies to taking advantage of lower energy prices to locate or relocate to the US. Preliminary analysis of the impact on the US economy suggests that these developments could deliver a 1.7-2.2 percent increase in GDP and 2.4-3.0 million additional jobs by 2030. Additional crude oil production would result in a significant reduction in the US net trade balance. The US would import less or no crude oil from its current suppliers—Canada, Mexico, Saudi Arabia, Latin America and West Africa, forcing them to find alternative markets. A dramatic expansion of US production could also push global spare capacity to exceed 8 million barrels per day, at

> which point OPEC could lose price control and crude oil prices would drop, possibly sharply. Such a drop would take a heavy toll on many energy producers who are increasingly dependent on relatively high energy prices to balance their budgets.[5]

The views expressed in *Global Trends 2030* are striking, especially because they come from a government report. Words like "tectonic shift" are rarely if ever found in staid federal presentations. However, the expression is justified.

In their "high scenario," the *Global Trends 2030* authors suggest that crude production from US reserves could reach twenty million barrels per day by 2020. This figure is one hundred fifty percent higher than the US Energy Information Administration's highest projection in its 2012 annual report,[6] issued just five months before the NIC document.

NIC bases its audacious projection in part on the dramatic breakthroughs in fracking technologies. The authors provide a detailed snapshot of the procedure's production and environmental aspects.

> Hydraulic fracturing, or fracking—a new technology to extract gas and oil from rock formations—is already making sizable differences in the ability of oil and gas companies to extract natural gas and oil from resources previously thought to be inaccessible. The technology will enable the release of natural gas and oil in sufficient quantities to drive down the cost of those energy resources and make substantial differences to the oil and gas import requirements of countries using fracking, as well as their dependence on coal. During the last five years the combined technologies of fracking and horizontal drilling have been an energy game-changer in the United States and other countries with large reserves of shale gas and oil.
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> Fracking technology was first developed and commercialized in the late 1940s. Since then over 2 million fracking stimulations of gas and oil have been completed. In fracking

[5] *Global Trends 2030: Alternative Worlds*, pp. 35-36.
[6] US EIA, *Annual Energy Outlook*, June 2012 [http://goo.gl/4ldbW], p. 95.

well operators pump a fluid (usually water) mixed with propping agent (usually sand) and a dozen or so chemical additives to control physical characteristics, such as viscosity, pH, surface tension, and scale prevention, at high pressure into a well bore. The pressure creates fractures that propagate through the rock formation; the propping holds the fractures open to allow the gas to flow through the opened porous formation once the well has been completed. The technology has evolved from its early days of using 750 gallons of fluid and 400 pounds of sand in a well to today's levels: fracking now uses over a million gallons of fluid and 5 million pounds of sand. The latest fracturing operations use computer simulations, modeling, and microseismic fracture mapping as well as tilt sensors, which monitor rock deformations. For fracking to be most efficient, the technology is coupled with horizontal drilling, a technique that became standard practice in the 1980s in oil and gas wells.

The coupling of fracking and horizontal drilling has provided oil and gas companies with access to numerous resources that were previously considered to be unusable. As a result, unconventional natural gas and oil have steadily become a larger portion of the gas and oil production in the United States. In the last five years, the increased supply and lower prices for natural gas have reduced the use of coal in the United States for power generation, thereby reducing carbon dioxide emissions.

The major hurdle that fracking faces in reaching its full potential to develop nonconventional gas and oil resources is the public concern that it will negatively impact the environment through water contamination, seismic inducement, and methane emissions. The fear of contamination of surface water and groundwater during site preparation, drilling, well completion, and operation and the risk to water resources for all users in the watershed are the primary environmental concerns of regulatory agencies.

Current research is focused on finding better ways to handle and treat the large quantities of water required and reducing significantly the amount of water used in fracking by using wastewater or mine water, liquids other than water, or compressed gases, including potentially carbon dioxide. Existing wastewater management techniques can mitigate water contamination by recycling the produced water or disposing it into deep wells. Deep-well disposal of produced water is the most common disposal technique, but at times it has been linked to seismic events in the area of a well site.

> Fugitive emissions of methane, a potent greenhouse gas, are another environmental concern. Although the combustion of natural gas produces less carbon dioxide than that of coal or fuel oil, that advantage could be obviated by fugitive emissions of methane during drilling, completion, and operation of an unconventional gas well. If these emissions are kept small (~1 percent of production), a net advantage of natural gas remains, but if they are large (7-8 percent of production), natural gas loses its greenhouse gas advantage over coal.[7]

Fracking's impact on the petroleum sector is captured in recent oil and gas production data. Figures 1 and 2 show oil output for Texas and North Dakota from 1981. The surge in output for both begins in January 2010. The rise corresponds to the acceleration in fracking activity in the Eagle Ford and Permian Basin areas of Texas and the rapid expansion in the Bakken field in North Dakota.

Reuters columnist John Kemp, at one point an analyst for a major trading company, has written extensively of late on the output jump tied to fracking. According to Kemp, the increase occurred as drilling companies upgraded their rigs and gained more experience with new technologies. His analysis began in early November. At that time, he wrote that North Dakota shale fields could rival Saudi Arabia's famous Ghawar: "Bakken's exponential growth and enormous reserves put it on course to produce more than 1 million barrels per day by the middle of next year, which will earn it a place in the small pantheon of truly elite oil fields."[8]

Kemp explained how the Bakken is a "continuous" reservoir rather than a conventional one:

> In a conventional oil or gas system, hydrocarbons are produced in a source rock and migrate through tiny pores or along fault lines before accumulating in a reservoir rock, from which they are produced.

[7] *Global Trends 2030: Alternative Worlds*, p. 37.
[8] John Kemp, "Is Bakken Set to Rival Ghawar?," Reuters, November 12, 2012 [http://goo.gl/aCpWw].

> The source rock must have a high proportion of organic material (typically at least 1-3 percent) to generate petroleum. It must be buried to the correct depth and temperature for the organic material to mature into oil (2000-5500 meters, 60-150 degrees centigrade) or gas (anything deeper than 5500 meters, and hotter than 150 degrees).
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> There must be sufficient cracks or porosity to allow the produced oil and gas to migrate from the source and accumulate in a reservoir rock. And the reservoir must be sealed by a cap to prevent the oil and gas migrating any further, allowing it to accumulate in sufficient concentrations to be extracted profitably.
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> Source, maturation, migration, reservoir and trap must all come together in exactly the right sequence. If any one of these elements is missing or occurs in the wrong sequence, oil and gas will not accumulate in a discrete pool.

Continuous-type resources (the US Geological Survey introduced this term) are different. In these reservoirs, the oil is deposited in source rock that may lie sandwiched between shale layers or in the shale itself. As Kemp and the NIC explain, until recently firms could not tap shale oil successfully. Horizontal drilling and fracking changed the situation. As Kemp concludes,

> Conventional super-giants such as Ghawar may never be discovered again, although exploration is pushing into new areas offshore and in the Arctic. But that may not matter if oil and gas can be wrung from more commonly occurring continuous deposits.

Kemp’s November 12 article must have triggered a ferocious response from peak oil proponents. These individuals and firms adhere to the views initially expressed by the late Shell geologist M. King Huppert. Huppert believed that crude reserves were finite and that production inevitably had to decline. Shale oil is an anathema to those who follow Huppert’s “Bell Curve” view.

Some peak oil supporters assert that Bakken production will peak at around seven hundred thousand barrels per day and then drop quickly. They no doubt responded to Kemp’s November 12 report with detailed analyses refuting his comparison of the Bakken and Ghawar.

Kemp provided more detail on the North Dakota field on November 21 in a column titled "Bakken Revolution Is Only Half-Complete."[9] After citing peak oil reports that assert Bakken output will top out at around seven hundred thousand barrels per day, a figure close to its current output, Kemp proves those studies wrong.

Kemp begins by noting that the peak pessimists base their argument on production from Bakken wells dropping quickly. Here they are correct, according to state officials. The average well produces around nine hundred barrels per day in the first year and then declines to four hundred twenty-five in the second, one hundred fifty in the third, and eighty in the fourth. According to one peak oil adherent, such declines require a price of $80 to $90 per barrel to break even.[10]

North Dakota officials disagree with that conclusion even though they accept the decline rate. They expect production to increase as roughly two thousand new wells are drilled annually for the next sixteen years to develop the "play." They believe output could reach 1.2 million barrels per day in the next three years and then be sustained for five to ten years. The state has sufficient rigs operating to achieve the target given the increased productivity rates.

Kemp also cites a state report that suggests drilling is now highly profitable. Referring to a presentation made by Lynn Helms, director of North Dakota's Oil and Gas Division, Kemp offers this observation:

> Bakken wells are far from as marginal according to the state. Bakken wells are expensive to drill and complete, at around $9 million each. But the average Bakken well drilled in 2012 will produce roughly 615,000 barrels of oil over 45 years, Helms explained to the tribal leaders.

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[9] John Kemp, "Bakken Revolution Is Only Half-Complete," Reuters, November 21, 2012 [http://goo.gl/G6rB5].
[10] Ibid.

> In its lifetime, an average well will pay $4 million in taxes to the government and $7.3 million in royalties to mineral owners, as well as operating expenses of $2.3 million and wages and salaries of $2 million. But after all those deductions, and the high upfront drilling cost, the average Bakken well will still generate net profits of about $20 million, Helms said.

The average cost of a Bakken well, then, is around $70 per barrel on an undiscounted basis if these calculations are correct (see Table 1). However, the estimate includes a profit of $20 million. Furthermore, most of the profit comes in the first year when half the reserves linked to a well are produced. This means Bakken output could still be profitable at $35 per barrel.

Column 2 in Table 1 shows the calculation of profitable production at $35. There I provide the North Dakota state data on drilling and operating costs and lifetime output. Royalties and taxes have been cut in half, though, because those payments are tied to the oil price. Also shown is the profit estimate, which drops from $20 million to $6 million.

As the alternative calculation shows, operations could continue even if crude prices fell to $35 per barrel. Indeed, if the Division's numbers are correct, the price paid to Bakken producers would have to hit $25 per barrel for profits to vanish. The right-most column in Table 1 presents this case.

The estimates assume royalty and taxes rise or fall proportionally with the oil price. Such an assumption accords with industry practice. They also assume that operational expenses remain the same regardless of price, as do drilling costs. If these costs decreased with a fall in oil prices, the zero-profit level would, of course, be even lower.

These calculations demonstrate that the profit opportunity from Bakken shale is large. Using the state's estimates again, the per-barrel profit rises at a rate of roughly $0.75 per barrel per dollar rise in price (see Figure 3). At $80 per barrel, roughly the current price for Bakken crude, the incentive to produce is substantial.

Furthermore, the significant decline in rates actually increases the incentive to drill. Drillers apparently can recover all their costs in the first year if, as suggested, half the well's production is recovered in that year.

Quick cost recovery further enhances the attractiveness of drilling shale oil. More than half a well's output occurs during the first year of operation. At a price of $70 per barrel, I calculate that fifty-five percent of the well's first-year production would cover the drilling costs, assuming royalties and taxes are paid from the first barrel of production.[11] At $90 per barrel, costs would be recovered in five months and, at $70 per barrel, costs would be recovered in seven months (see Table 2).

The implication, then, is producers can move ahead with shale projects with less fear of a sharp price drop than those working conventional fields. A company investing hundreds of millions to produce from a large conventional field at a constant rate for a number of years must gamble that prices will remain relatively stable over the period for it to recover costs. For this reason, firms engaged in conventional exploration and production will use relatively low price assumptions when making investment decisions. If the period for full cost recovery is, say, five years, a company may use a breakeven price as low as $50 per barrel to test the feasibility of drilling. In contrast, firms developing shale projects can use much higher threshold levels even if the

[11] The calculation is as follows. Drilling costs account for $9 million, according to the state. If costs are to be covered first, revenues from the first one hundred seventy-five thousand barrels would be required, assuming the producer netted $52 per barrel after deducting royalties and taxes from a wellhead price of $70. The one hundred seventy-five thousand barrels represent fifty-five percent of the well's first-year production of three hundred fifteen thousand barrels, assuming an average rate of production of nine hundred barrels per day as the state does. The implication, then, is that at $70 per barrel, the average North Dakota well turns cash-flow positive by the seventh month.

conventional project producer and shale field developer assume prices follow the same random walk.[12]

Shale project developers also can more easily protect their cost recovery through hedging than can conventional field developers. On organized futures markets, open interest and trading volume in contracts expiring within twelve months accounts for much of the market activity. In fact, seventy-five percent of open interest in WTI futures is in the first twelve contracts. This coincides nicely with the concentration of production from shale fields.

Moreover, the WTI market's contango today provides a very nice incentive to hedge, as Figure 4 shows. Thus, producers can easily hedge the share of output that covers all costs and lock in the first year's profits.

The size of each shale well also makes it easier to hedge. A producer need sell only between two hundred ten and two hundred fifty futures contracts per well to cover the costs of a single project. Sales of such a small number would not affect a market. In contrast, a producer seeking to hedge the costs of a large offshore drilling project would need to sell one hundred or one thousand times as many contracts. Such amounts could easily move markets. The developer of the offshore project would also need to sell contracts expiring two, three, or four years ahead if it wanted contract expiration to correspond with the anticipated revenue flow. As noted above, there is very limited open interest and volume in such contracts.

[12] Dixit and Pindyck point out that the dynamic or Markovian process determining prices should logically influence a producer's decision to invest. If prices follow a random walk—or a random walk with drift—the firm considering investing will calculate the probability that a price will fall below some critical level within the investment and development horizon. The shale developer benefits because the period to recover full costs and indeed almost all a project's profits occurs in a much shorter period. Thus, a shale producer today might be willing to move ahead with an investment even if it feared much lower prices in a year because all costs would be recovered in seven months. A conventional field developer, in contrast, might delay or slow investment out of worry a price fall would compromise its investment. See Avinash K. Dixit and Robert S. Pindyck, *Investment under Uncertainty* (Princeton, NJ: Princeton University Press, 1994).

In short, shale producers enjoy several advantages. First, the individual projects are small and discrete. This makes it possible to respond quickly to changing conditions. Second, the high rate of initial production makes it possible to recover costs quickly, reducing the danger from prices tumbling. Third, by luck, futures market trading makes it very easy to hedge costs and lower risks.

Shale project developers enjoy one further advantage: decreasing costs. Here again, Kemp's reporting is invaluable. In a December 11 article, he reviews the economy-wide experience associated with learning by doing. He notes that researchers found that the most common "progress ratio" (the impact on costs from experience) is around eighty-one percent, meaning, according to Kemp, that unit costs fall twenty percent for each cumulative doubling in output.

Kemp then notes that firms drilling for shale have become increasingly productive over time. One rig could drill eight wells per year in 2008. This number rose to eleven wells per year in 2011 and was projected to rise to twelve wells in 2012.[13] After reviewing industry experience, he suggests that drilling costs rose rapidly between 2008 and 2012 as firms rushed to expand.

> The full extent of efficiency improvements has been masked by the inflation in drilling and fracturing costs over the past decade. The upsurge in oil and gas drilling activity has been so sudden it has caused acute shortages and massive cost escalation in everything from fracking sand and guar gum to experienced rig crews and petroleum geologists.

He then adds that costs should decline in coming years as shortages are addressed:

> The goal for all companies in the exploration, production and oilfield services sectors is to create highly standardized "frac factories," which would bring the assembly-line

[13] John Kemp, "Frackers Learn by Doing," Reuters, December 11, 2012 [http://goo.gl/W25pS].

> efficiencies of Henry Ford's motor manufacturing to oil and gas production, raising output and squeezing costs.

The shale revolution will also benefit from replacement of older drilling rigs by newer, more sophisticated machinery. The older machines used motors powered by direct current. These provided greater power and speed control. New machines powered with alternating current engines have greater precision. One service company, Helmerich & Payne, advertises that its newest rigs can drill a well in fifteen days compared to thirty days for older rigs. The per-day charge on the new rig is higher than that rate charged for the older rigs. However, the per-well cost reportedly has dropped by $500,000 due to the rig's greater productivity.[14]

Given the apparent profitability of drilling, one might ask why production is not increasing at a faster rate. The obvious one-word answer is "constraints." There are at least three of these: logistics, rig availability, and labor availability. Each is being solved.

The **first constraint, logistics**, involves significant obstacles that limit how much oil can be moved from North Dakota. The pipelines that run through the area are at capacity. What is more, they take the oil south. Railroads are being used to remedy the situation. Burlington Northern Santa Fe and Canadian Pacific are working to boost capacity. They will raise takeaway volumes to one million barrels per day by the end of 2013.[15] At the same time, new terminals designed to load unit trains of one hundred to one hundred twenty cars are being rushed to completion. Their

[14] John Kemp, "Faster, Deeper, More Power in NA Rig Market," Reuters, December 11, 2012 [http://goo.gl/LyUqc].
[15] Javier Blas, "Buffett's Boost to US Shale Revolution," *Financial Times*, November 21, 2012 [http://goo.gl/V7Eyz].

capacity was put at two hundred thousand barrels per day at the end of 2011. By the end of 2012, it was expected to rise to five hundred fifty thousand barrels per day.[16] This number will increase.

Unit trains are preferable to pipelines at this point because they can move crude east and west. The Gulf Coast is already well supplied with crude. Furthermore, as noted here repeatedly, if the Keystone XL Pipeline is completed, it will increase surplus crude in the Gulf and probably drive down the domestic crude price.[17] Trains that move east and west will allow refiners to move crude to facilities on the East and West Coasts. Refiners in New York and Pennsylvania have started building large unloading facilities for crude. ConocoPhillips has gone so far as to secure a fifty thousand barrel per day supply of crude for its Bayway, New Jersey refinery.[18] Enbridge and another firm are building a facility to offload eighty thousand barrels per day in Philadelphia.[19] PBF has expanded the rail facility at its Delaware refinery to receive forty thousand barrels per day of crude by mid-2013 and one hundred ten thousand barrels per day by year's end. The oil is coming from western Canada and North Dakota.[20] Delta Airlines is following the lead of these firms, seeking to source significant crude volumes from the Midwest.[21] Irving Oil is also boosting its facilities in Canada. At the beginning of 2011, its refinery could receive two rail cars

[16] "Rail Shipments of Williston Basin Crude to Jump in 2012: Logistics Expert," *Platts Global Alert*, March 29, 2012.
[17] See *The Petroleum Economics Monthly*, "Keystone XL Pipeline as a Trojan Horse: A Gift from OPEC that Will Keep on Giving?," August 2011.
[18] Bridget Hunsucker, Esa Ramasamy, and Joshua Sterns, "Global-Phillips 66 Ink Deal to Take Bakken Crude to Bayway Refiner," *Platts Oilgram Price Report*, January 9, 2013, p. 7.
[19] "Enbridge Announces Plans to Rail Bakken Crude to Philadelphia, in 2013," *Platts Global Alert*, November 26, 2012.
[20] Leslie Moore Mira, "PBF Delaware Refinery Switches to Canadian, Bakken Crudes, Away from Brent," Platts, August 24, 2012.
[21] "Delta Expects to Run Bakken Crude at Trainer by April," Platts, December 12, 2012.

per day. By the end of 2011, the capacity had increased to one hundred cars or sixty thousand barrels per day.[22]

One unit train contains sixty to sixty-five thousand barrels of crude. While statistics on use are not available, it appears that one train can make roughly thirty trips per year, meaning each train has the capacity of five thousand barrels per day. Two hundred trains would be required to move one million barrels per day. Adding up the numbers for New Jersey, Philadelphia, and Delaware, one finds that at least two hundred forty thousand barrels per day and perhaps as much as five hundred thousand barrels per day of Bakken and Canadian crude are moving to East Coast refiners. This works out to between four and eight unit trains per day. More would flow if loading facilities, unloading facilities, and rail cars were available.

Additional oil volumes are being moved west to refineries in California and Washington. BP is shipping crude to its Anacortes refinery, as is Tesoro to its nearby facility. Phillips 66 is also shipping crude to two refineries in California. Tesoro's CEO has indicated the company wants to move fifty thousand barrels per day to its Washington refinery to cut use of expensive Alaskan crude.[23]

Tank car capacity is also limited. To remedy this, refiners and traders have been rushing to buy cars. Phillips 66 has agreed to purchase two thousand (the equivalent of twenty unit trains), which in theory could deliver one hundred thousand barrels per day to its various refineries. The cars will be used to move oil east to New Jersey and west to California and Washington.[24]

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[22] "Irving Receives Bakken Crude at New Brunswick Refinery," *Platts on the Net*, May 31, 2012.
[23] "Tesoro Lifts Volumes of Bakken Rail Project," Reuters, August 2, 2012 [http://goo.gl/he9xR].
[24] "Phillips 66 to Buy 2,000 Rail Cars to Transport Oil," Reuters, June 8, 2012 [http://goo.gl/oSJ2e].

The availability of advanced rigs is also a problem. As Kemp explains, drilling companies are having much greater success with advanced “Type 3” land rigs. These rigs have electric motors, offer better control, and can drill further. Production expansion will depend on the rate these rigs become available.[25]

Over the last four years, the change in the rig fleet has been impressive. As Kemp notes, “In 2008, the U.S. fleet consisted of around 1,000 older mechanical rigs, another 600 with silicon-controlled rectifiers (SCRs) and direct current (DC) motors, and just 250 units employing alternating current (AC) motors.”[26] By 2012, the number of mechanical rigs was halved and the number using AC motors doubled.

These new rigs can drill more wells in a year than older rigs. Kemp reports the newest wells can drill twenty-four wells per year instead of twelve as in the past. Thus industry capacity has increased, even though the number of rigs available has declined.

The capacity, however, cannot keep pace with demand, especially given the financial returns offered with oil prices near $100 per barrel. Thus one can expect rigs to be added as fast as they can be built.

The availability of trained labor will constrain expansion. Labor shortages plague drillers and those fabricating rigs. The Bureau of Labor Statistics (BLS) reports that unemployment in North Dakota was 3.2 percent in December, the lowest in the nation. Generally, a rate below four percent implies that everyone seeking work can find a job.

[25] John Kemp, “Faster, Deeper, More Power in NA Rig Market,” Reuters, December 11, 2012 [http://goo.gl/LyUqc].
[26] Ibid.

North Dakota's low unemployment should be attracting workers from other parts of the country. This inflow will eventually boost the capacity of firms to drill in the state. However, this will take time because everything is in short supply, housing in particular.

Limits on transportation capacity, rig availability, and the labor force will slow the expansion rate in North Dakota and in other areas where shale drilling is increasing. Over time, these constraints will be addressed, greater efficiencies will be achieved, and capacity expansion will continue. In addition, new, faster, and lower-cost methods of developing shale will be introduced. One can expect continued growth in production.

The success achieved in North Dakota will be matched in other fields. Indeed, rapid production increases have already occurred in Texas in the Eagle Ford and Permian Basin. In the near term, this will also happen in some of the older fields in Oklahoma, Colorado, and Kansas. By the end of 2013, the fracking revolution will have spread to New Mexico and Kansas.

Fracking is already moving ahead rapidly in other countries. Producers in certain areas of Canada are already well along in applying the techniques. Argentina has negotiated a contract with Chevron to explore a potentially rich area. China is also pushing ahead despite a water shortage in many areas. Other nations will follow. The technological advances of US exploration and production firms will be adopted overseas by license or copying. Ultimately, the technology will be in use across the globe.

The expansion of shale oil and production will likely create a very different global supply-and-demand landscape for both fuels by 2020. Today, the characteristics of the balance are blurry.

While the International Energy Agency attempted to sketch out the situation in the *World Energy Outlook* released November 2012, it underestimates the magnitude of the change tied to shale.

The problem confronting the IEA and the US Energy Information Administration is they are wedded to the conventional thinking that holds world oil reserves to be finite. The IEA's deficiency in this regard is captured in its response to this question: "Are we finding enough crude oil to sustain production?":

> The simple answer is: no. In the oil-supply module of the World Energy Model, which is used to generate the projections, discovery rates are derived from country-by country estimates of ultimately recoverable resources. Production in each country is then projected, based on investment in different categories of resources: existing fields (including those in production and those awaiting development) and new fields yet to be found, as well as unconventional resources.[27]

There is a very simple interpretation for this statement: "We, the IEA, have no idea what is going on with shale oil, thus we choose to ignore it." As the IEA's report explains early in the discussion, the agency relies on reserve estimates published by publications such as *Oil & Gas Journal*.[28]

Many years ago, Professor Adelman noted the mistake in this approach. In article after article, he explained that published estimates of reserves bore no relationship to either the amount of oil in the ground or the amount of oil that would actually be recovered. Time and again, he tried to show why modeling approaches such as those followed by the IEA or EIA were fruitless. Despite the respect he enjoyed, his views were ignored. Yet today, his writings demonstrate why the IEA"s method of predicting supply is essentially a silly exercise:

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[27] International Energy Agency, *World Energy Outlook 2012*, p. 105.
[28] IEA, p. 97.

> In the United States, annual crude production is about three billion barrels, "proved reserves" about 30 billion, oil-in-place about 300 billion barrels. I cannot emphasize too strongly that the 300 billion represents conventional oil deposits *now* known and previously exploited. It has nothing to do with deposits "to be discovered," nor with oil shales.[29]

In a 1991 essay, he expanded on this view, noting that few agreed with him. (He might have added that consensus does not determine a proposition's truth. If it did, Columbus would have fallen off the edge of the world.)

> My view of supply has not been shared by all. The 1973 price explosion was greeted by many economists, and not the least distinguished, as the long-delayed inevitable scarcity. In this view, temporary forces had just happened to keep all mineral prices flat or declining—for a remarkably long time. A great structure of the theory and calculation now arose as an upside-down pyramid, resting on one assumption. As a Nobel Laureate wrote: [Hotelling] "applied the calculus of variations to the problem of allocation of a fixed stock over time." All of the recent literature is essentially based on Hotelling's paper.[30]

Adelman then added this observation:

> The fixed stock does not exist. We cannot rescue the concept by making the "economic proportion" of the unknown total in-ground. That is circular reasoning. For the economic proportion is an implicit unverifiable forecast of all future output, of what will be worth producing through time. That depends on changes in ***science and technology*** [emphasis added], which will determine future costs and price, hence future output. One cannot estimate these costs and prices by starting with their assumed result. In fact, ultimate

[29] Adelman, "Economics of Exploration for Petroleum and Other Minerals," *Geoexploration* 8 (1970), pp. 131-150, reprinted in *The Economics of Petroleum Supply*, pp. 65-87.
[30] Adelman, p. xiii. The quote is from Kenneth Arrow, "Hotelling," in Eatwell, Milgate and Newman (eds.), *The New Palgrave Dictionary of Economics* (London: Macmillan Press, 1987), p. 67.

> production is unknown. The much larger amount in the ground is unknowable and irrelevant, a nonbinding constraint.[31]

By 2020, it will be clear that long-term forecasts issued by EIA and IEA in 2012 were way off the mark. No blame should be assigned for the error because projections made at a time of dramatic structural change are invariably way off the mark. All that can be said at this point is that the amount of oil produced from non-OPEC sources will rise sharply. Furthermore, the volume of natural gas produced by the United States and other countries with large shale reserves will also increase.

Figures 5 and 6 show the IEA's most recent projections for natural gas and oil production for non-energy-exporting countries. Also shown are production possibilities that could emerge from the shale revolution. The projections clearly diverge. By 2025, the IEA sees US production at around 11.6 million barrels per day of oil. My scenario puts output at sixteen million barrels per day. I note that my forecast is conservative compared to the high case issued by the National Intelligence Council, which put production at twenty million barrels per day in 2020.

The projections of natural gas production also diverge. By 2025, the IEA sees US output at seven hundred sixty-five billion cubic meters (twenty-seven trillion cubic feet) My scenario puts US production at one trillion cubic meters (thirty-five trillion cubic feet).

Some will be startled by the two forecasts I offer. However, the situation is changing so fast that the IEA's current forecast for US natural gas output in 2015 requires a two-percent *decline* in US output from 2012. Quite simply, the production situation in the United States is shifting rapidly for oil and natural gas. I see increases in oil and gas output continuing but at slower rates going

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[31] Adelman, p. xiii.

forward (half the recent rate in the case of natural gas). I explain my view by noting I am not wedded to an outdated model of oil and gas supply that fails to account for the shale revolution that has occurred over the last three years.

The impact of revolutions in oil and gas supply is particularly difficult to model for two reasons. First, there is no history. Without history, modelers must fall back on economic theory, a step economists at the IEA and EIA seem incapable of taking. Second, reserves have lost their meaning. As noted, the reserves being tapped through shale drilling have not been included in resource bases. Thus the surge in oil and gas production in the US comes almost as manna from heaven.

I attempt to capture the revolution’s impact in Table 3. The table shows additions to US output from shale production from 2013 to 2018 assuming eleven hundred of the Type 3 wells Kemp describes are spudded every year for the next five years. According to the Helms data, shale wells produce around nine hundred fifteen barrels per day the first year. Production then falls off sharply. Eleven hundred wells would add one million barrels per day to US output the first year. By 2018, output from each well brought into production in 2013 decreases to eighty-two barrels per day and the collective output of the eleven hundred 2013 vintage wells is ninety-one thousand barrels per day.

One can also observe that the aggregate output from the fifty-five hundred wells drilled over the five-year period reaches 1.9 million barrels per day. This second figure is relevant to the discussion of future supply. Production will keep surging over the next ten to twenty years as costs continue to decline and recovery techniques improve. It is this technological process, driven mostly by smaller firms that probably never talk to the IEA, that will make a mockery of current projections.

It would take only a fraction of rigs operating in the United States today to drill these wells. If the numbers put forward by Helmerich & Payne, one of the nation's leading drilling companies, are correct as few as forty-eight and certainly no more than one hundred advanced rigs would achieve the goals shown here. At present, at least four hundred and possibly as many as six hundred advanced rigs are available.[32] Thus, although it seems impossible, the United States could be looking at an increase of as much as six to eight million barrels per day in oil production by 2020.

I note again here that the National Intelligence Council raised the possibility of even higher production in its *Global Trends 2030: Alternative Worlds* report.[33] Surprisingly, the NIC scenario is not totally unreasonable. If all other logistical issues are addressed, the current drilling fleet could allow the US to boost output to twenty million barrels per day by 2018. The probability of everything working so perfectly is probably zero but the numbers are compelling.

IEA and other conventional forecasts of oil and gas production apparently have fallen victim to the "digital camera effect" or DCE. The DCE can be seen in Figure 7. This graph tracks constant dollar consumer expenditures on photo finishing in the United States. Note that expenditures peaked at more than $6 billion constant dollars in 1999 and then dropped more than fifty percent by 2005.

[32] John Kemp, "Faster, Deeper, More Power in NA Rig Market," Reuters, December 11, 2012 [http://goo.gl/LyUqc].
[33] See *Global Trends 2030: Alternative Worlds*, p. xii.

The decline in consumer expenditures on photo finishing can be explained by the introduction of the first affordable digital camera in 2000, followed by the advent of phones with embedded cameras around 2005. (The iPhone came out in 2007.) These innovations obliterated the photo-finishing business and the film camera.

Forecasts made by planners at Kodak or Fuji Film as late as 2000 no doubt showed the photo-finishing business continuing to grow slowly, possibly reaching $10 billion in constant dollars by 2013. Instead, sales collapsed. Kodak was forced into bankruptcy by the DCE.

The disruptive innovations that opened shale gas production will undermine the old oil world order, just as digital cameras and the iPhone undermined the photo-finishing world. Conventional forecasts of future oil and gas production in the US and other countries with shale resources—such as those prepared by the IEA—will prove disastrously wrong thanks to the effects of technological advances in shale drilling.

It goes without saying that the production boost will put increasing pressure on current oil producers, particularly Russia and OPEC. Their response to the surge in low-cost supplies will have a significant impact on the world over the next few years.

II. Implications of Promoting US Oil and Gas Exports

Promoting oil and gas exports from the United States will probably accelerate the shale revolution. The US has not been a significant exporter of crude oil or natural gas for sixty years. Current laws actually prohibit crude oil exports. Natural gas can be exported but only under certain circumstances. Several firms that invested heavily in facilities to import liquefied natural gas to the United States are now aggressively pushing to have natural gas exports permitted so as to make use of the billion dollar facilities they built.

The issue of natural gas exports is contentious, though. Firms such as Dow Chemical are working aggressively to limit exports, arguing they would raise prices. Dow executives suggest that natural gas exports could adversely affect the US natural gas recovery.[34] A Department of Energy study confirms Dow's worst fears, estimating that natural gas exports would boost prices between thirty-six and fifty-four percent by 2018 from baseline levels.[35]

Similar views will be expressed by opponents of crude oil exports. As with natural gas, interested parties such as large consumers and refiners will likely oppose the idea, some with extreme passion.

However, opposition to exports may also reflect conventional thinking, thinking that is no longer correct for two reasons: the end of the resource constraint and the new drilling paradigm. Historically, nations have coveted their resources, believing them to be finite and valuable. Thus China has limited exports of rare earth metals in a failed effort to force firms to move electronics business to that country. The same thinking is found at Dow and among many politicians. The accepted view is the United States has much larger but still limited natural gas resources. The reserves should be used to rebuild US manufacturing and not be sold to other countries.

The reserve constraint, though, is gone. Today there is plenty of natural gas in the United States for domestic use and export. Foreign purchases may even boost the production level rather than

[34] Tennille Tracy, "Gas Price Could Rise with Higher Exports," *The Wall Street Journal*, January 20, 2013 [http://goo.gl/PrC46].
[35] Chris Newkumet, "US LNG Exports Would Hit Gas Prices: EIA," *Platts Oilgram News*, January 20, 2013, p. 11.

raise prices. Whether prices rise or fall depends on the shape of the supply-and-demand curve, as well as the movement of each curve.

One can add that US and foreign firms can protect themselves by hedging. The natural gas market is so robust that Dow could guard against price increases in 2013 and the four or five following years by buying gas in futures or forward markets.

(An interesting question that will be addressed in a future paper concerns the response of the natural gas forward price curve to announcements of export approvals. One would think forward prices would rise if there were concerns regarding the impact of future exports on prices. There seems, though, to have been no impact.)

Opponents of exports may also have failed to note that costs of finding and producing incremental volumes of oil and natural gas in the US are falling. Today, the breakeven cost of producing oil from the Bakken is $25 per barrel. Next year, it could fall to $20 or even lower if drillers keep driving down costs while increasing the amount of oil found. The same is true for natural gas.

Development of oil and gas resources, it seems, has become a declining cost business. This finding reverses one hundred years of history. Energy economists have always correctly asserted that oil and gas finding costs increase over time. They based this assertion on the fact that the size of discoveries tended to decrease while costs went up as exploration moved steadily into more difficult areas. Costs were and are lower to develop wells in shallow waters rather than deep and in the Gulf of Mexico rather than the Arctic. However, as prices rise, drilling in more challenging and expensive areas occurs because that is where large reserves are thought to lie.

Shale is different. Costs seem to decline with every well, even if the well sites are becoming more challenging. An "experience" or "learning" curve may apply today to the development and production of oil. The concept is old and simple. Economists have observed that in many activities, unit costs decline as the number of units produced increases.[36] Kemp suggests there is evidence that costs associated with drilling for shale oil and gas are characterized by a learning curve.[37]

If Kemp is correct, then consumers in the United States would benefit if exports were encouraged because costs would fall as drilling increased. In the absence of a resource constraint, a surge in drilling—done of course in a fashion acceptable to those living nearby and in accordance with tight environmental rules—would lead to increased output and lower prices. Forward buying by those planning to export would provide the extra financial cushion required to boost drilling.

Naturally, critics will latch onto the caveat regarding acceptable practices and tight environmental rules. They are right to be cautious. The rush to boost output must not lead to devastation of land, water, roads, or air quality. Exports should be encouraged, though, if these considerations can be met. The result will be greater US supply, greater pressure on world oil and gas prices, ultimately lower prices, and quite probably stronger global economic growth.

Domestic companies such as Dow that worry they will be priced out of the market can buy reserves in the ground today (they are inexpensive) or hedge on futures markets. Foreign firms can do the same.

[36] See Louis E. Yelle, "The Learning Curve: Historical Review and Comprehensive Survey," *Decision Science* 10 (1979), pp. 302-328 [http://goo.gl/koxnT].
[37] John Kemp, "Frackers Learn by Doing," Reuters, December 11, 2012 [http://goo.gl/W25pS].

As is the case with production forecasts, the conventional wisdom is almost certainly wrong. Increases in exports will provide an incentive to boost output and will likely cause prices to be even lower than had exports not been approved.

III. Opening Pandora's Box

The end of the resource constraint and the lifting of "petroausterity" (the sickness that has afflicted most industrialized countries since 1973) will bring a new and quite possibly more complicated set of problems to the world. The list may be endless. However, three obvious difficulties come to mind immediately.

> First, countries that have built their economic plans on steadily rising income from oil and gas exports need to rethink their strategy quickly. Russia, for example, could face enormous troubles if the surge in unconventional supplies reduces oil and gas prices sharply. Increasing political instability cannot be ruled out.
>
> Second, the obstacles confronting those pushing for aggressive increases in conservation and greater renewables use will expand dramatically. Falling crude oil, gasoline, and natural gas prices will encourage greater hydrocarbon consumption and discourage efforts to conserve. Some countries such as the United States may overcome this by boosting mandated renewables use. But other nations that have had to sacrifice growth at the altar of high oil prices will move strongly to take advantage of low-priced indigenous oil and gas supplies if they can.
>
> Third, efforts to deal with global warming have just become infinitely more complex. Those countries that have shale resources, and there are many, will rush to capitalize on their opportunity. Production will surge in unexpected places such as Argentina. Best industry practices may be observed more in words than actions. Releases of methane, a very poisonous warming gas, could spike as wells

> are drilled rapidly and carelessly. The consequences could be disastrous for the world as a whole, even if the countries with resources finally get their economic revenge.

I chose "Opening Pandora's Box" as this section's title to emphasize the potential disasters that await the world.

Removal of the resource constraint could destabilize countries that have planned their future on ever-rising oil prices. Economists often write of the "needs" of oil-exporting nations. Time and again, one sees predictions of prices remaining high because such countries "need" high prices to sustain their economic situations.

Such pronouncements are nonsense, of course. The "income needs" of an individual have utterly no relationship with the individual's actual income. If it were otherwise, bankruptcy courts would not be needed and no dwelling would ever go into foreclosure.

It is the same with resources. One reads often of lectures delivered by ministers of oil-exporting nations to officials in consuming countries on the importance of high prices. Invariably, the high-price proponent warns that investment in new fields and new production will flag if prices fall.

One of the most ridiculous examples of this thinking can be found in a paper by Sergei Komlev. Komlev heads the pricing directorate at Russia's Gazprom. In the paper, he rails against those who would allow natural gas to be priced as another commodity. In a bold remark, he makes this assertion:

> Our empirical analysis indicates that a pricing mechanism based on supply and demand does not meet the criteria for price fairness because it is not supportive of investment in the industry.[38]

The author goes on to fault almost all pricing mechanisms that rely on the market, especially those in the US where futures markets have driven natural gas prices well below the level needed, *he believes*, to maintain investment. Komlev goes so far as to complain that some firms had the gall to "hedge" production and thus continued to invest even as prices fell below his preferred level.

When one reads Komlev's paper carefully, one sees a very angry individual who has somehow become enriched in a commodity-exporting country through luck or graft. Such individuals are not uncommon in Russia and many other oil-exporting nations. They believe they and their firms or countries deserve high prices. Furthermore, they are willing to threaten those in consuming countries with dire consequences if buyers do not continue to pay high prices. Time and again, oil producers have put the gun to consumer heads, as the following Platts report illustrates:

> OPEC on Thursday warned the European Union that too-low oil prices could "break the momentum" of upstream investment and threaten future supply security, according to a joint statement issued after a regular ministerial meeting between the two sides in Brussels.[39]

The fact is that market forces that bring low prices affect political security in oil-exporting countries. Those who attack the market results are afraid not for oil or natural gas consumers but for their own survival.

[38] Sergei Komlev, "Pricing the 'Invisible' Commodity," Discussion Paper, Gazprom Export, January 11, 2013 [http://goo.gl/pji7o], p. 19.
[39] "OPEC Warns Europe Low Oil Prices Could Threaten Supply Security," *Platts Global Alert*, June 28, 2012.

They are right to worry. Bruce Riedel, now a senior fellow at the Brookings Institute but in the past an adviser to US presidents on Middle East issues, has written an open letter to President Obama. In it, he warns of the impact of revolution in Saudi Arabia. He urges the United States to reestablish trust with the Kingdom to ward off a potential uprising.[40] Riedel's unstated but clear message is the US must take steps to keep oil prices high. Otherwise, a Saudi revolution is sure to follow with disastrous consequences for us.

Riedel is partially correct. Revolution will come to some oil-exporting countries as prices fall. He and Komlev are wrong, though, regarding the willingness of any nation to stop the increase in oil production to prevent the crisis. Sixty-five years ago, President Eisenhower imposed mandatory quotas on oil imports to protect the US oil industry. His action created battles between the US Northeast and domestic oil producers for almost two decades.[41] Komlev and Riedel would apparently have the United States impose output limits on US producers to help sustain world oil prices. Such an action is unlikely.

Instead, increased output will put pressure on markets. Prices will fall. Revolutions will follow. Production from some countries will be disrupted. Prices will then rise as they did following the Iranian revolt. The increases will be followed by further pressure on prices. It will be a very messy cycle.

It is too late to stop it.

[40] Memorandum to President Obama from Bruce Riedel, "Revolution in Riyadh," January 17, 2013 [http://goo.gl/ynI7r].
[41] See Milton Russell and Douglas Bohi, *Limiting Oil Imports* (Baltimore, MD: Resources for the Future, Johns Hopkins Press, 1978).

Removal of the resource constraint will complicate efforts to boost energy conservation and renewables use. Poor Amory—Amory Lovins that is. Founder and president of the nonprofit Rocky Mountain Institute (RMI), Lovins has made a career of pushing energy conservation and alternative fuels as a solution to the nation's energy problem. He has based his analysis on the assumption that energy prices will rise inexorably. Over the years, Lovins has advocated development of solar power and alternative materials for automobile construction among many other strategies. RMI has consulted extensively with companies such as Wal-Mart on ways to reduce energy use. As proponents of "negawatts," Lovins and his colleagues have championed more aggressive employment of technologies to cut energy consumption. For Lovins, a winner of a MacArthur "Genius Grant," technology represents the way forward.

RMI's most recent publication, *Reinventing Fire*, is its most ambitious effort in this regard. In the press release for the book, the organization asserts that it "maps pathways for running a 158% bigger US economy in 2050." In a separate article summarizing the work, Lovins writes of "a farewell to fossil fuels." In the piece, he details what it will take to achieve the RMI goal:

> This transformation requires pursuing three agendas. First, radical automotive efficiency can make electric propulsion affordable; heavy vehicles, too, can save most of their fuel; and all vehicles can be used more productively. Second, new designs can make buildings and factories several times as efficient as they are now. Third, modernizing the electric system to make it diverse, distributed, and renewable can also make it clean, reliable, and secure.[42]

Some of the adjustments proposed to reduce oil and gas use are good and will serve the world well in the future. Some represent overkill and would divert scarce capital from more productive activities, effectively slowing the per-capita income growth rate. Most of the RMI ideas fall in

[42] See Amory Lovins, "A Farewell to Fossil Fuels," *Foreign Affairs* 91, No. 2 (March/April 2012) [http://goo.gl/iPR34], p. 136.

this category. If enacted, they would doom millions if not billions of people to further decades of poverty. Lovins has been an extremist, albeit a popular one, in this arena for at least thirty years.

His appeal, as well as the attractiveness of his ideas to many, can be traced directly to the first oil crisis forty years ago and the stubborn persistence of high prices since. The enthusiasm for conservation, renewable fuels, and oil displacement has increased with each upward ratchet in price. In his efforts, Lovins has drawn more and more from technologically oriented people, especially of late. Individuals such as Vinod Khosla and Bill Joy, for example, have sought to apply their success and experience from Silicon Valley to energy. These and other billionaires see no reason why they cannot apply their technology skills to designing systems that reduce oil use and boost renewables use. Amory Lovins has been their Pied Piper.

Soon someone will write a sequel to “A Farewell to Fossil Fuels.” The title will be “A Farewell to Amory.” Lovins was prescient. Technology will solve the economic problems associated with high-priced oil. However, the solution will not be found in conservation, renewable fuels, or other high-tech alternatives for energy use. Instead, the application of technology to crude oil and natural gas production from areas previously inaccessible promise to create bountiful supplies of very-low-cost energy resources.

While Lovins and his supporters have pushed every possible technical and regulatory approach to reduce oil use and accelerate renewables consumption, others sought to find technological solutions for shale development and production. The latter won the race. Their success will drive down oil and gas prices, making many of technologies to cut energy use developed by Lovins’ followers uneconomic and infeasible.

The increased availability of hydrocarbon fuels produced from shale will slow or stop the conservation programs spearheaded by Lovins, especially if prices drop to low levels. As Komlev asserts, a “pricing mechanism based on supply and demand does not meet the criteria for price fairness.” In short, as President John F. Kennedy once noted, “Life is not fair.”

Technology has made the intractable problem of global warming enormously more complicated by unlocking oil and gas from shale. The years 2012 and 2013 will probably be marked by future historians as the time when everyone became convinced global warming was a serious problem and that human activity had contributed to it. This assumes, of course, that we survive climate change.

The technological breakthroughs that opened shale reserves to development could substantially increase fossil fuel combustion. Furthermore, the production process, if done incorrectly, might release significant volumes of methane, a gas fifty times more potent as a warming agent than carbon dioxide.

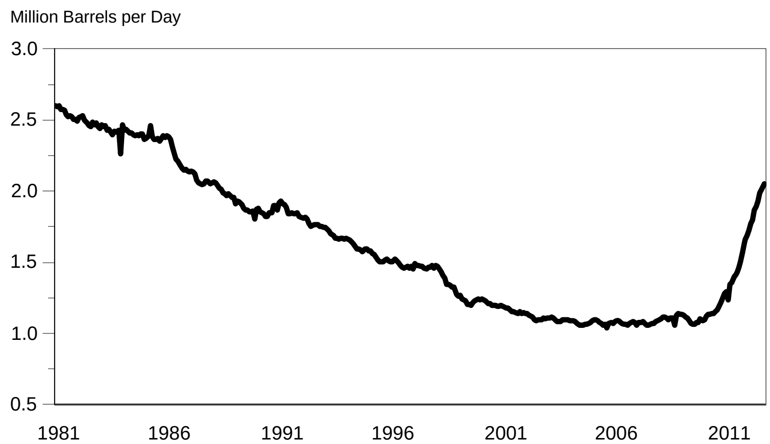
At the same time, the basic fracking technology that has expanded shale production is essentially the poor man’s way of escaping petroausterity. The technology, while expensive, costs far less than developing offshore or even large onshore reserves. Furthermore, shale reserves are distributed far more widely. Thus it is likely that, by 2020, many countries will have shale development projects underway. Many of these nations have objected at international climate change meetings to the unwillingness of large industrialized countries to acknowledge their right to increase emissions in order to move from their underdeveloped status to equality with the latter. Those with large shale reserves will tap them regardless of the wishes of others.

Furthermore, nations entering into shale development will not have to rely on major oil companies or suppliers. By 2020, the large, well-established firms that have dominated the oil industry historically will likely have lost control of the production process. Shale output will proliferate across the globe. Greenhouse gas emissions may proliferate as well.

Unfortunately—and possibly tragically for future generations—the likely outcome can be predicted. The solution, if any, cannot.

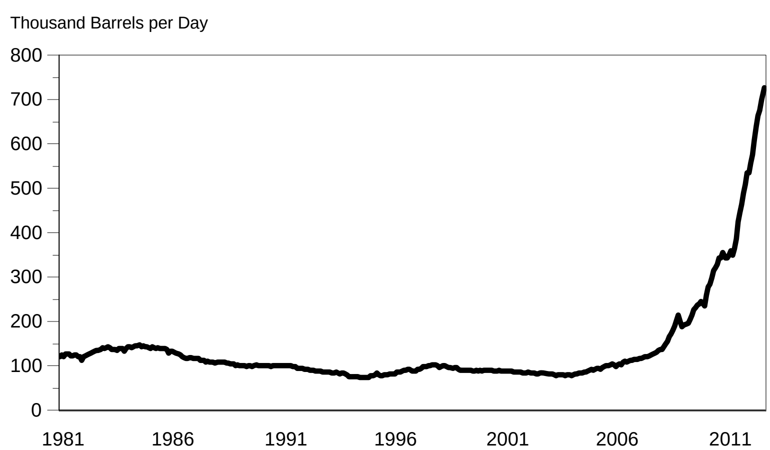
Figures and Tables

Figure 1
Monthly Texas Crude Oil Production, 1981-2012



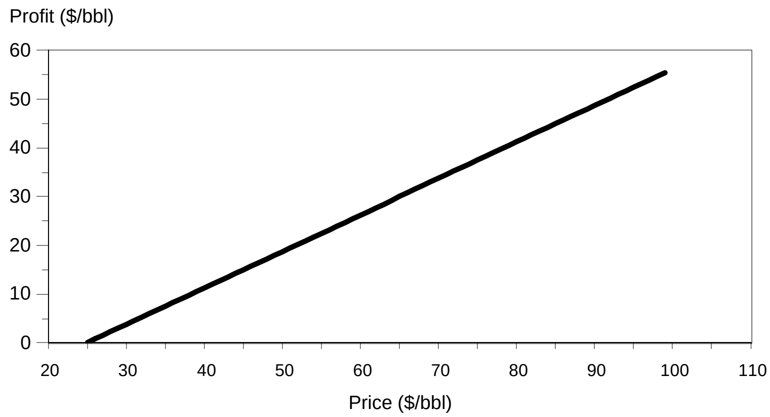
Source: PKVerleger LLC.

Figure 2
Monthly North Dakota Crude Oil Production, 1981-2012



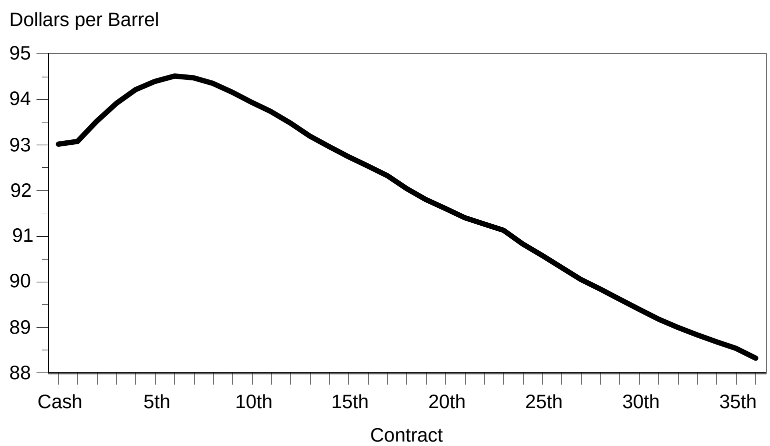
Source: PKVerleger LLC.

Figure 3
Per-Barrel Profit from Bakken Production vs. Oil Price at Well Head in North Dakota



Source: PKVerleger LLC.

Figure 4
Forward Price Curve for WTI on January 4, 2013



Source: PKVerleger LLC.

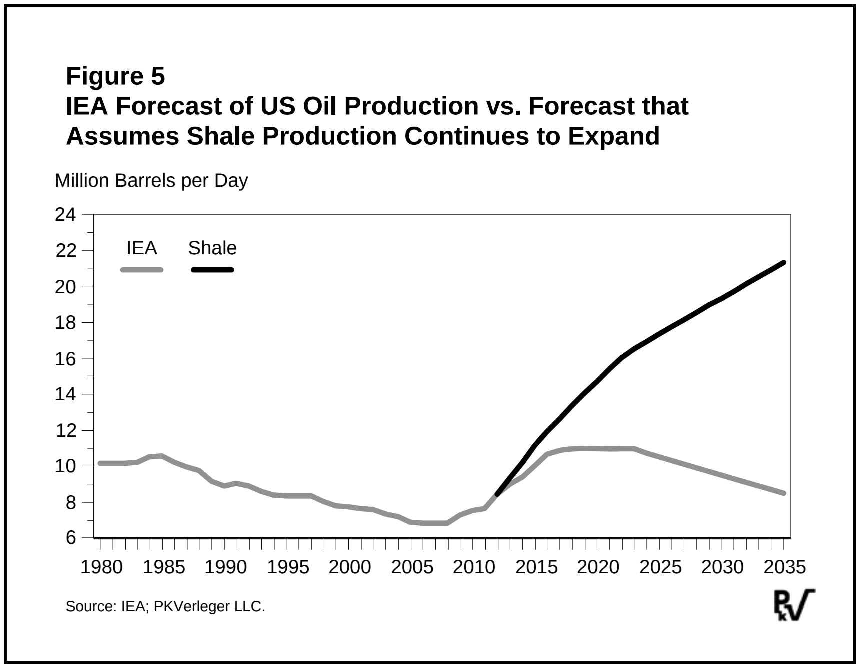


Figure 5
IEA Forecast of US Oil Production vs. Forecast that Assumes Shale Production Continues to Expand
Million Barrels per Day
24
22
20
18
16
14
12
10
8
6
IEA
Shale
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Source: IEA; PKVerleger LLC.

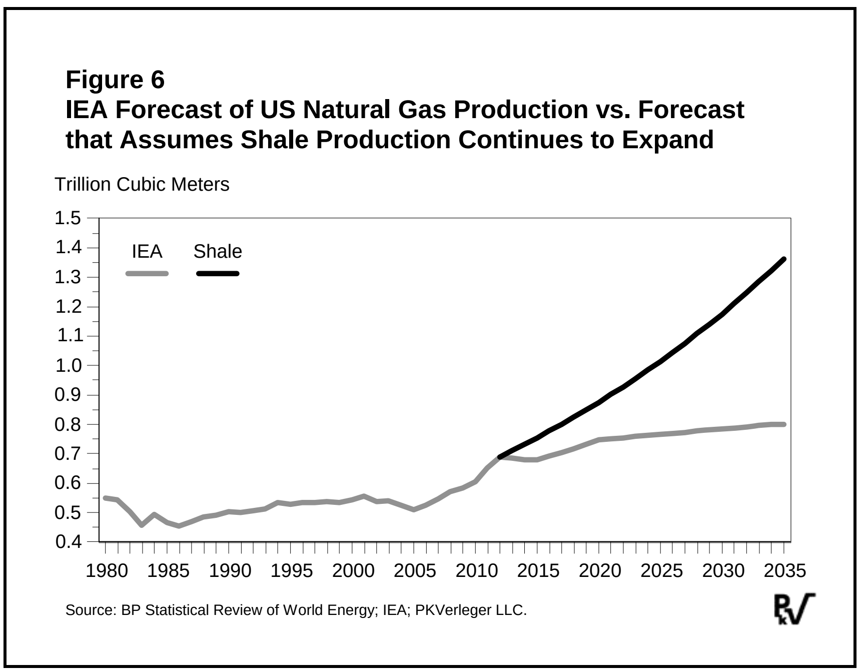
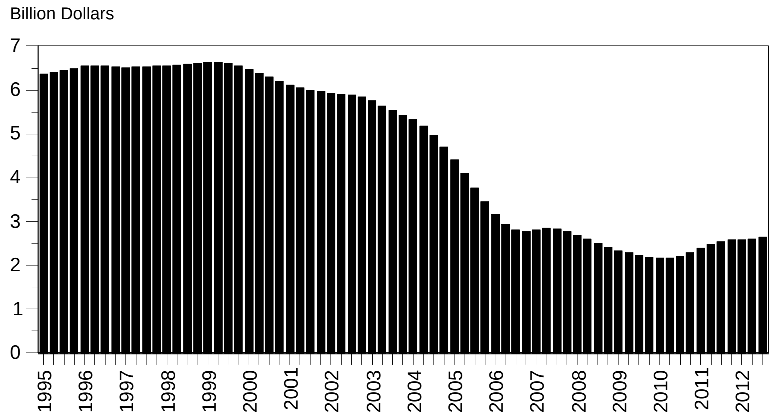


Figure 6
IEA Forecast of US Natural Gas Production vs. Forecast that Assumes Shale Production Continues to Expand
Trillion Cubic Meters
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
IEA
Shale
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Source: BP Statistical Review of World Energy; IEA; PKVerleger LLC.

Figure 7
The Digital Camera Effect: Consumer Spending on Photo Finishing in Constant Dollars, Quarterly, 1995-2012



Source: US Bureau of Economic Analysis.

Table 1. Calculations of Profitability for a Bakken Well According to North Dakota's Oil and Gas Division

	State Case ($ Million)	$35/bbl Case ($ Million)	$25/bbl Case ($ Million)
Drilling Costs	9.0	9.0	9.0
Operating Costs	2.3	1.5	1.5
Royalties	7.3	3.7	2.4
Taxes	4.0	2.0	1.3
Profits	20.0	6.0	0.0
Total	42.6	22.2	14.3

Note: Assumes production over well life of 615,000 barrels.

Source: PKVerleger LLC.

Table 2. Months Required to Recover $9 Million Drilling Cost after Deducting Operating Costs, Royalties, and Taxes

Oil Price ($/bbl)	Months
90	5
80	6
70	7
60	9
50	11
40	15
30	28

Source: PKVerleger LLC.

Table 3. Contribution to Production from Eleven Hundred Wells Drilled Each Year Using Helms/Continental Resources Data (Thousand Barrels per Day)

	Production in Year (Read Down)					
Contribution from Wells Drilled in Year (bbl/day)	2013	2014	2015	2016	2017	2018
2013	1,000	472	165	124	91	91
2014		1,000	472	165	124	91
2015			1,000	472	165	124
2016				1,000	472	165
2017					1,000	472
2018						1,000
Total	1,000	1,472	1,637	1,761	1,851	1,942

Source PKVerleger LLC.

