The Changing Face of World Oil Markets

By James D. Hamilton*

This year the oil industry celebrated its 155th birthday, continuing a rich history of booms, busts and dramatic technological changes. Many old hands in the oil patch may view recent developments as a continuation of the same old story, wondering if the high prices of the last decade will prove to be another transient cycle with which technological advances will again eventually catch up. But there have been some dramatic changes over the last decade that could mark a major turning point in the history of the world's use of this key energy source. In this article I review five of the ways in which the world of energy may have changed forever.

1. World oil demand is now driven by the emerging economies

For most of the twentieth century, the major developed economies were the primary consumers of oil, and their annual consumption grew at a very predictable rate. Figure 1 plots the combined oil consumption of the U.S., Canada, Europe and Japan since 1984. The annual growth in these countries' consumption over 1984-2005 can barely be distinguished from a deterministic linear trend, increasing each year by about 440,000 barrels a day. But the last decade brought a rather astonishing reversal in that trend. Oil consumption in the developed countries has fallen an average of 700,000 b/d every year since 2005, reaching a level as of the end of 2012 that is 8 mb/d lower than one would have predicted in 2005 on the basis of a simple extrapolation of the historical trend.

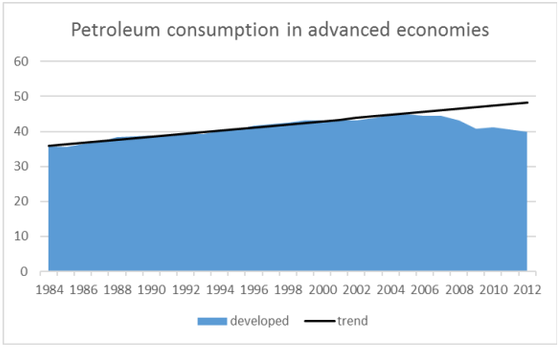

Figure 1. Petroleum consumption in the U.S., Canada, Europe and Japan, 1984-2012, in millions of barrels per day. Black: linear trend estimated 1984-2005. Data source: EIA (http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=5&aid=2).

One factor slowing growth in oil demand from the developed countries was the significant loss in income associated with the Great Recession. Figure 2 shows that U.S. real GDP fell significantly in 2008-2009, and has yet to return to its historical trend. However, since 2009 U.S. GDP has been growing at its historical rate even as U.S. oil consumption continued to decline. The primary factor in the latter was the doubling in the price of oil since 2005. It was higher oil prices, not slower income growth, that was most important in forcing reductions in fuel use in North America, Europe, and Japan.

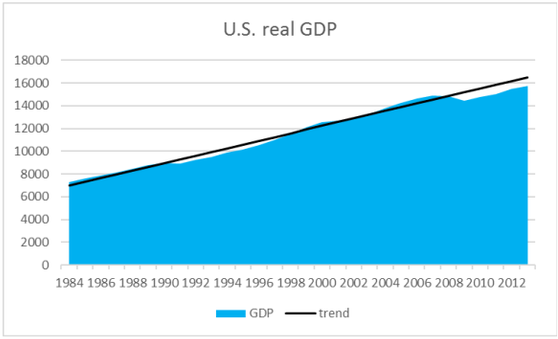

Figure 2. U.S. real GDP, 1984-2013, in billions of chained 2009 dollars per year. Black: linear trend estimated 1984-2005. Data source: FRED (http://research.stlouisfed.org/fred2/series/GDPCA).

The story for the world's emerging economies has been quite different, as seen in Figure 3. Although these countries accounted for only 40% of the world total in 1984, their trend line grew at 650,000 b/d annually over 1984-2005. And whereas consumption in the developed economies fell significantly since 2005, that in the emerging economies grew even faster than it had over the period from 1984-2005. China alone accounted for 57% of the global increase in consumption since 2005. The last decade has brought an astonishing improvement in income to people in China and a number of other countries, one side effect of which was a big increase in these countries' consumption of petroleum. In 1980, the emerging economies accounted for about a third of global oil consumption. Today the figure is 55%.

These breaks in consumption trends also call for a break in thinking from the framework that many analysts traditionally used to make long-run energy forecasts. The dominant approach used by most analysts in 2005 was to project forward the historically stable trends seen in plots like Figure 1 and assume that somehow the world would find a way to continue to increase production to fulfill the projected growth in demand. For example, Figure 4 (reproduced from Benes, et. al., 2012) shows in different colors the projections for world oil consumption through 2020 made each year over 2001-2010 by the U.S. Energy Information Administration (EIA). The actual path (in black) fell far short of those projections, because supply did not increase at the historically predicted pace. I next discuss some of the reasons why that was the case.

2. Growth in production since 2005 has come from lower-quality hydrocarbons

Before going further it is worth focusing on exactly what we are referring to by the total quantity of oil produced or consumed. The figures produced above

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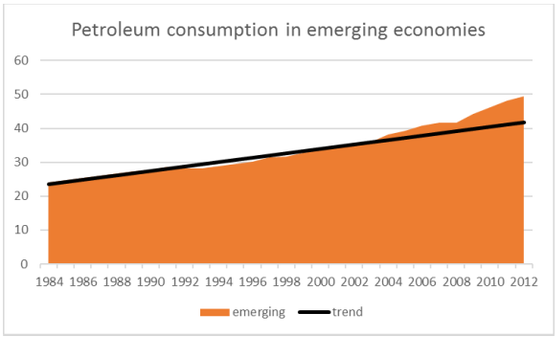

Figure 3. World petroleum consumption outside of the U.S., Canada, Europe and Japan, 1984-2012, in millions of barrels per day. Black: linear trend estimated 1984-2005. Data source: EIA (http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=5&aid=2).

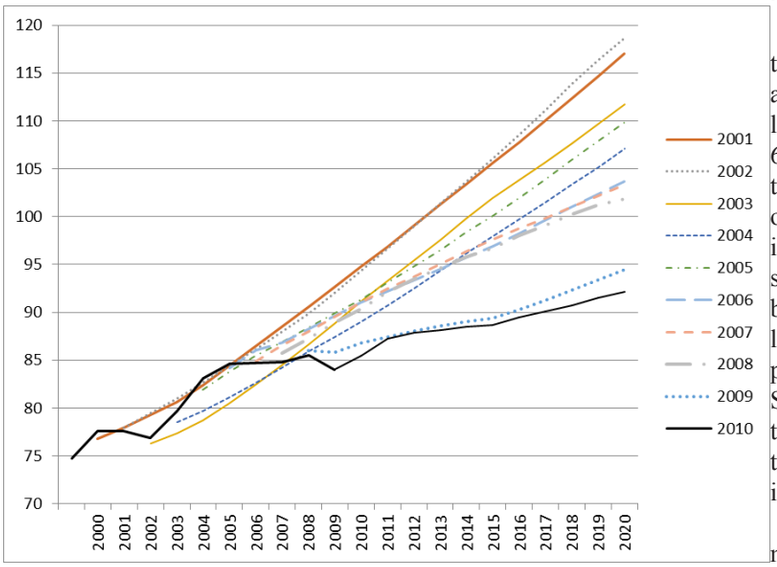

Figure 4. Projections of world oil consumption (total liquids in mb/d) made by EIA in each year 2001-2010, along with actual historical path. Source: Benes, et. al. (2012)

all used the concept of "total oil supply" employed by the EIA. Figure 5 summarizes how the 84.6 mb/d in total liquids produced globally in 2005 broke down in terms of its various components. Eighty-seven percent of this total came from field production of crude oil and lease condensate, which are essentially liquids taken directly out of the ground. A minor contribution came from natural gas liquids (NGL). These are hydrocarbons that are in gaseous form at ambient temperature and pressure, but require less cooling and pressure to liquefy than single-carbon methane, the component of pure natural gas. Because these are more valuable products than methane, if present in sufficient quantities (so-called "wet gas"), it pays natural gas producers to separate these products out and their liquid volume is counted as part of the measure of total liquids production used above. Other even less-important factors historically in "total liquids production" were refinery process gain (a consequence of the fact that the volume of refined products exceeds the volume of the starting crude oil) and "other liquids", which chiefly refers to biofuels.

Although these other components made a relatively minor contribution to the total in 2005, they account for more than half of the increase in total liquids production since 2005, as seen in Figure 6. Does it make sense to add natural gas liquids to barrels of crude oil in arriving at a total measure of total oil production? Of the NGL currently being produced in the United States, about 70% represents two-carbon ethane or three-carbon propane.[1] A barrel of crude oil typically contains about 5.8 million British Thermal Units (BTU), while a barrel of propane has 3.836 mBTU and ethane only 3.082.[2] Sometimes private oil companies even add production of methane (on an equivalent BTU basis) to their liquid oil production to report their production in units of "barrel of oil equivalents."

For some purposes, these various hydrocarbons might indeed be viewed as equivalent or close substitutes. For example, natural gas can replace fuel oil for heating, ethane provides a useful petrochemical feedstock, and propane is even used in some specialized transportation settings. But if the objective is to produce a liquid fuel for cars or planes, natural gas or natural gas liquids are a poor substitute. From an economic point of view, summarizing the substitutability between different energy sources has a very clear answer—we only have to look at the price to see how close substitutes different fuels really are.

The black line in Figure 7 plots the dollar price of a barrel of West Texas Intermediate crude oil. The red line shows the price of natural gas on an equivalent BTU basis (that is, the dollar price of a million BTU of natural gas multiplied by 5.8). These two tracked each other reasonably closely up until 2005, after which oil began to pull away. Today you'd pay four times as much to buy a BTU in the form of oil compared to natural gas. This reflects the fact that U.S. production of gas and wet gas increased much faster relative to their respective demands than has crude oil. An energy-producing company that reports its natural gas production on a "barrel of oil equivalent" basis is clearly doing a disservice to shareholders who care about how profitable the company actually is.

The blue and green lines in Figure 7 plot the price of propane and ethane, respectively, again on a relative BTU basis compared to crude oil. These stayed fairly close to crude oil during the big price run-up in 2008, but ethane has since pulled away, and now sells for about the same price as natural gas. After a brief spike from heating use during the unusually cold North American winter in 2013-2014, propane is now back to selling at a 40% discount to crude. Clearly in an economic sense, a barrel of natural gas liquids is not nearly as valuable today as a barrel of crude oil.

Adding biofuels as equivalent to field production of crude oil is even more problematic. About 40%

of U.S. corn production is currently devoted to producing ethanol (Wisener, 2014), purely as a result of extensive mandates and subsidies. While some have argued that more energy is used in the process of growing the crops and producing the product than is actually contained in the ethanol, there does appear to be some modest net energy gain (Hill, 2006). But adding biofuels to a measure of total liquids production seems to be motivated more by political considerations than by economics or science.

3. Stagnating world production of crude oil meant significantly higher prices

If one looks only at field production of crude oil, the picture becomes quite stark. Field production increased worldwide by only 2.3 mb/d between 2005 and 2013. That compares with a predicted increase of 8.7 mb/d from extrapolating the pre-2005 trends in consumption growth for developed and emerging economies, and that's without even taking account of the dramatic acceleration in demand from the emerging economies. It's also instructive to relate these numbers to global growth of real GDP. According to the 2014 IMF World Economic Outlook database,[3] world real income increased by 27.7% between 2005 and 2013. If we assume an income elasticity of 0.7, for which Cseresklyei, Rubio, and Stern (2014) provide abundant empirical support, we would have expected that in the face of a stable price of oil, production should have increased by 19.4%. The actual increase in field production of crude oil was only 3.1%, consistent with a shortfall of 12 mb/d.

The story behind the doubling of real oil prices since 2005 is thus quite simple—if prices had not risen, growth in demand, particularly that coming from the emerging economies, would have outstripped production. A big price increase was necessary to reverse the trend of growing consumption in the developed economies. In the following sections I explore some of the reasons why world oil production stagnated during this period of strong demand.

4. Geopolitical disturbances held back growth in oil production

One factor holding back production in a number of locations today is geopolitical unrest. The biggest single contributor over the last three years has been Libya. A civil war in 2011 led to the overthrow of Qadhafi and near cessation of exports. The subsequent peace proved to be temporary, and production has recently again been sharply curtailed as a result of labor disputes and conflicts between warring militias. Sanctions continue to reduce Iran's production, and attacks on oil infrastructure keep Nigeria's production below its potential. About 400,000 b/d is currently lost as a result of open conflict in Sudan and Syria. All told, the EIA estimates that these and other unplanned disruptions reduced world oil production by 3.3 mb/d in June 2014 (see Figure 8).

If all of this production were to return next year, it would eliminate a third to a half of the shortfall calculated above. In this sense one could argue that geopolitical disruptions are a major part of the story. However, it is misleading to view geopolitical events such as those tabulated in Figure 8 as temporary aberrations. An examination of the history of some of the key oil-producing regions should remind us that much bigger disruptions than these are fairly common and usually have quite long-lasting effects. For example, the top panel of Figure 9 plots crude oil production from Iraq since 1973. Iraq's war with Iran, which began in September of 1980, was associated with an immediate drop in Iraq's oil production of 3 mb/d. But the war went on (and continued to exert a negative effect on production) until 1988. It was only two years later that Iraq

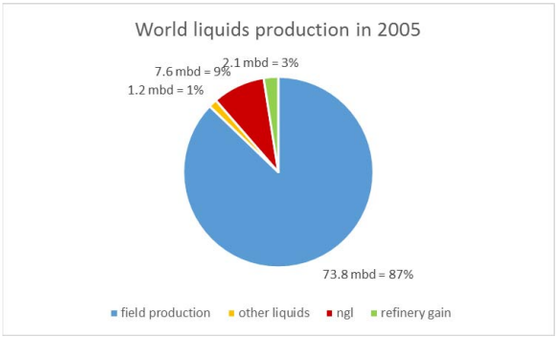

Figure 5. Total liquids production in 2005. Data source: EIA (http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm).

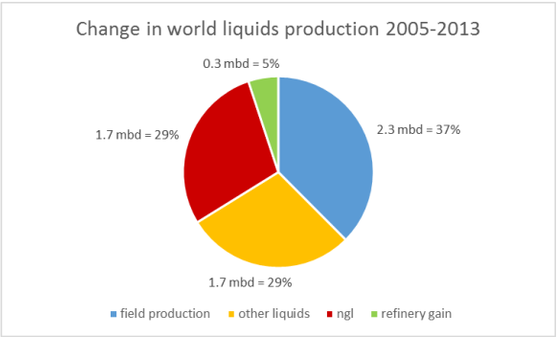

Figure 6. Amount of increase total liquids production between 2005 and 2013 that is accounted for by various components. Data source: EIA (http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm).

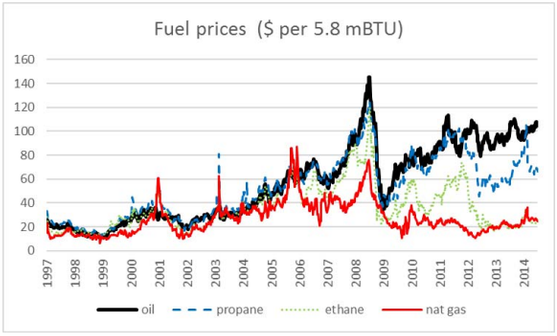

Figure 7. Prices of different fuels on a barrel-of-oil-BTU equivalent basis (end of week values, Jan 10, 1997 to Jul 3, 2014). Oil: dollars per barrel of West Texas Intermediate, from EIA (http://tonto.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RWTC&f=D). Propane: FOB spot price in Mont Belvieu, TX [(dollars per gallon) x (1 gallon/42 barrels) x (1 barrel/3.836 mBTU) x 5.8], from EIA (http://tonto.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EER_EPLLPA_PF4_Y44MB_DPG&f=D). Ethane: FOB spot price in Mont Belvieu, TX [(dollars per gallon) x (1 gallon/42 barrels) x (1 barrel/3.082 mBTU) x 5.8], from DataStream. Natural gas: Henry Hub spot price [(dollars per mBTU) x 5.8], from EIA (http://tonto.eia.gov/dnav/ng/hist/rngwhhdd.htm)

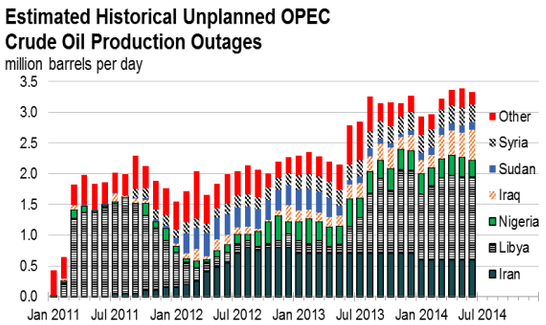

Figure 8. Global oil supply disruptions, Jan 2011 to June 2014. Source: constructed by the author from data provided in EIA, Short-Term Energy Outlook (http://www.eia.gov/forecasts/steo/report/global_oil.cfm).

invaded Kuwait. Again the loss in production was dramatic, and although this war was resolved relatively quickly, sanctions continued until the Gulf War of 2003, which brought its own set of new disruptions. Iraq's geological potential led Maugeri (2012) to expect it to make a major contribution to world oil production over the next five years. But recent geopolitical events in that country make it clear that's not going to happen.

The history of Iran (second panel in Figure 9) relates a similar lesson. Although the revolution of 1978 resulted in an immediate loss of over 5 mb/d, the country also lost many of its engineers and organizational infrastructure. Iranian production has never returned to levels of the early 1970s, and we will see when (if ever) production returns to its levels from before the recent sanctions. And in the case of Libya (bottom panel of Figure 9), the overthrow of Qadhafi occurred in 2011, but we are still discussing its "temporary" consequences three years later. One has only to read the most recent news from Iraq and Israel to conclude that perhaps we should consider ourselves fortunate that production from the Middle East is as high as it is presently. A big new drop in oil production rather than a sudden increase seems a more likely next outcome of the current political turmoil.

Moreover, the initial big run-up in oil prices came in 2008, well before the latest events in Libya, Iran, or Syria. Global field production of crude was flat between 2005 and 2008, despite the absence of a major identifiable geopolitical disruption, and despite the strong growth in demand from emerging countries. Furthermore, blaming the ongoing production shortfall on geopolitical events invites the more fundamental question of why the only sources of supply are in such unstable parts of the world. Why weren't supplies found elsewhere to make up the difference? I turn to this question in the next section.

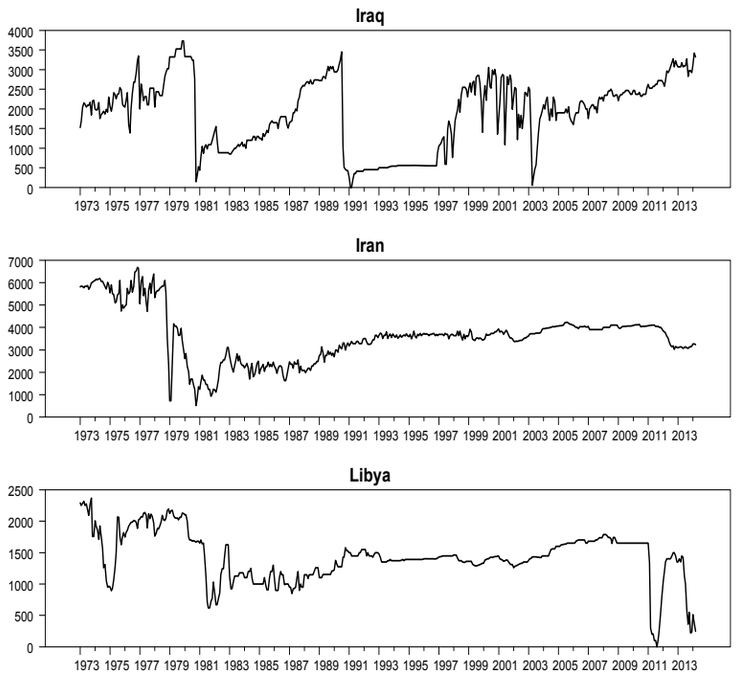

Figure 9. Field production of crude oil from Iraq, Iran, and Libya, Jan 1973 to Mar 2014, in thousands of barrels per day. Data source: EIA, Monthly Energy Review, Table 11.1a (http://www.eia.gov/totalenergy/data/monthly/#international).

5. Geological limitations are another reason that world oil production stagnated

The top panel of Figure 10 plots monthly oil production for all of OPEC, of which Saudi Arabia (bottom panel) accounts for about a third all by itself. Whereas the dramatic changes in production in the countries in Figure 9 often resulted from geopolitical events, most of the swings in Saudi production were the result of deliberate calculations, with the kingdom decreasing production when the market was weak and increasing production when the market was strong. Historically Saudi Arabia acted as the world's primary swing producer and maintained excess production capacity in order to be able to play that role. Projections such as those in Figure 4 assumed that the kingdom would continue to do so, with an assumption of ever-increasing Saudi and OPEC production filling the gaps between projected demand and supply.

But the bottom panel of Figure 10 shows that this isn't what happened. Saudi Arabia has continued to some extent to make modest changes in production in response to demand, decreasing production for example in the recessions of 2001 and 2007-2009. But apart from these minor adjustments, Saudi production has been remarkably flat for over a decade.

Some analysts maintain that this again represents a deliberate market decision, and that most OPEC members could achieve big increases in production any time they wanted. This view is hard to reconcile with evidence such as that in Figure 11, which shows that stagnant production from the Middle East has coincided with a dramatic increase in drilling effort in the region. There is a temporary drop

in the reported number of drilling rigs in January 2006 because Baker Hughes decided to no longer include Iran in their count after that date. There was also a modest decline during the Great Recession, consistent with the observation noted above that the decline in OPEC production in 2008-2009 was very much a deliberate response to market conditions. But the overall picture is that the Middle East countries have been devoting ever increasing resources to upstream development and yet have very little additional oil production to show for it.

In the case of oil produced by the major international companies that conclusion is even more compelling. Figure 12 shows that combined production from the 11 largest publicly-traded oil companies has fallen by 2.5 mb/d since 2005, despite a tripling of their capital expenditures.

Depletion of older reservoirs and the high cost of developing new resources are unquestionably part of the explanation. For example, production in the North Sea has moved increasingly north since the 1960s in search of more oil, but total production from the area has nevertheless been declining for the last 13 years, as seen in the top panel of Figure 13. Production from Mexico's Cantarell, once the world's second-largest producing oil field, has also been declining significantly since 2004. The earlier growth in Mexican and North Sea production had made a significant contribution globally, accounting for 12% of the world total in 2003 (see the bottom panel of Figure 13). But between 2005 and 2013, the combined production from Norway, U.K., and Mexico fell by 2.9 mb/d. The contribution from these three countries alone is at least as important as the geopolitical considerations noted in the preceding section.

It is also interesting to take a look at the history of production in individual U.S. states, which is summarized in Figures 14-15 and Table 1. Production from Pennsylvania, where the oil industry began in 1859, peaked in 1891, and in 2013 was at a level only 1/6 of that achieved in 1891. But despite falling production from Pennsylvania after 1891, U.S. production continued to increase, because of the added boost from Ohio (which peaked in 1896) and West Virginia (which peaked in 1900). And so the story continued, with increases in overall U.S. production despite declines from the areas first exploited, for nearly a century. Looking at the United States as a whole, production continued to climb every year through 1970, although production from many individual states was well into decline before that date.

Alternatively, one can summarize U.S. production in terms of broader categories. Field production from the lower 48 states (not counting production obtained from tight geologic formations using the now-popular horizontal fracturing drilling methods) was 5.5 mb/d lower in 2013 than it had been in 1970 (see Figure 16). The decline in production was only partially offset by development of Alaska's supergiant Prudhoe Bay field and other resources (which peaked in 1988) and offshore production (which peaked in 2003).

More recently, the decline in U.S. production has turned around dramatically with the exploitation of tight oil formations, whose 2.9 mb/d increase since 2005 more than offset the combined 0.6 mb/d drop in conventional lower 48, Alaska, and offshore production. Indeed, the net gain in U.S. production of 2.3 mb/d since 2005 by itself accounts for all of the increase in field production worldwide discussed in Section 3 above. Tight oil plays in the Bakken in North Da-

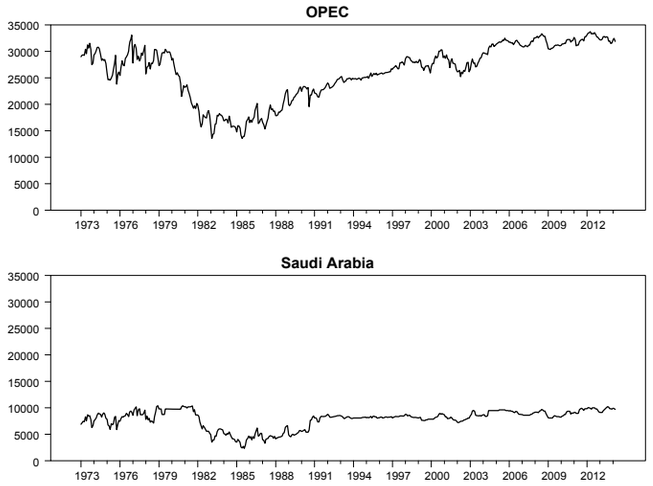

Figure 10. Field production of crude oil from OPEC and Saudi Arabia, Jan 1973 to Mar 2014, in thousands of barrels per day. Data source: EIA, Monthly Energy Review, Table 11.1a (http://www.eia.gov/totalenergy/data/monthly/#international)

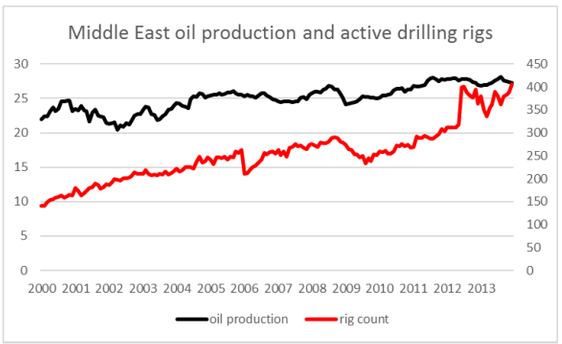

Figure 11. Middle East oil production and active drilling rigs, Jan 2001 to Dec 2013. Black line: total liquids production from the Middle East, in millions of barrels per day, from EIA (http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm). Red line: number of drilling rigs active in the Middle East (right scale), from Baker Hughes (http://phx.corporate-ir.net/phoenix.zhtml?c=79687&p=irol-rigcountsintl).

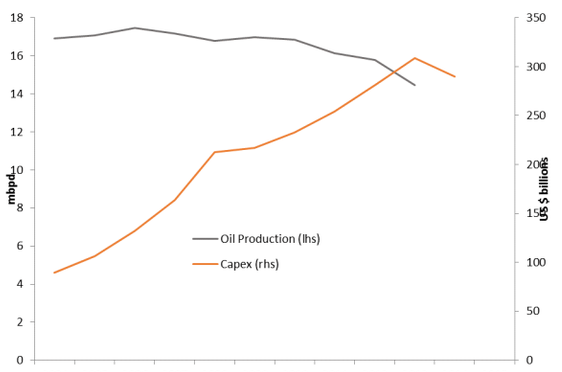

Figure 12. Total oil production and capital expenditures for the major international oil companies, 2004-2013. Includes XOM, RDS, BP, CVX, STO, TOT, PBR, PTR, ENI, REP, and BG. Source: updated from Kopits (2014)

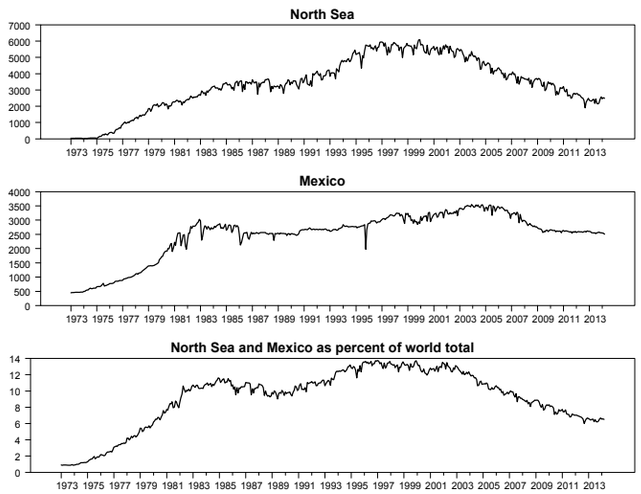

Figure 13. Oil production from the North Sea and Mexico, Jan 1973 to March 2014. Top panel: combined field production of Norway and the United Kingdom in thousands of barrels per day, from EIA, Monthly Energy Review, Table 11.1b. Bottom panel: sum of Norway, U.K., and Mexico production as a percent of world total

kota and the Niobrara in Colorado have brought production in those states to all-time highs (Table 1). Many analysts are optimistic that the trend of growing production from this resource will continue for the next several years, with the EIA's Annual Energy Outlook 2014 predicting that tight oil could bring total U.S. oil production back near or above the 1970 peak before resuming its long-term decline.

But even if this forecast proves accurate, it is abundantly clear that it would not return real oil prices to their values of a decade ago. One reason is that it is much more costly to produce oil with these methods. Although estimates of the break-even cost vary, we do know that the most of the companies producing from the tight oil formations have a negative cash flow (Sandrea, 2014)—they are spending more than they are bringing in at current prices. Although companies are presumably doing so in order to acquire an asset that will be productive in the future, it's also well documented that production from typical tight-oil wells falls to 20% of peak production within two years.[4]

So far development of oil from tight formations has occurred almost exclusively in the United States, though other countries including Russia, China, Argentina, and Libya also have promising geological potential.[5] But separate logistical obstacles may make it difficult to replicate the U.S. success elsewhere on a near-term basis. U.S. advantages include exploration and drilling assets that can be quickly moved, infrastructure to transport the product, mineral rights, ability to raise capital quickly, and political stability. That other countries can replicate the U.S. success at lower cost seems doubtful. Rather than a force pushing oil prices back to historical lows, it seems more accurate to view the emerging tight-oil plays as a factor that can mitigate for a while what would otherwise be a tendency for prices to continue to rise in the face of growing demand from emerging economies and stagnant supplies from conventional sources.

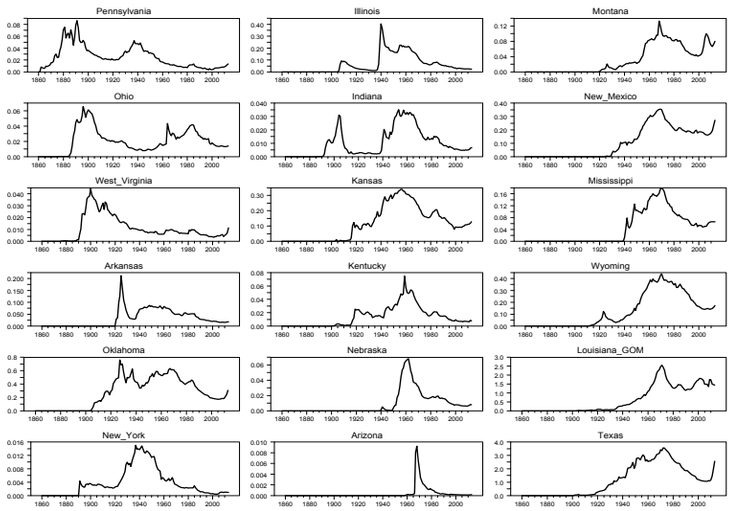

Figure 14. Annual production (in mb/d) from 18 U.S. states that peaked earliest, 1860-2013. Updated from data sources detailed in Hamilton (2013)

6. Conclusions

Although the oil industry has a long history of temporary booms followed by busts, I do not expect the current episode to end as one more chapter in that familiar story. The run-up of oil prices over the last decade resulted from strong growth of demand from emerging economies confronting limited physical potential to increase production from conventional sources. Certainly a change in those fundamentals could shift the equation dramatically. If China were to face a financial crisis, or if peace and stability were suddenly to break out in the Middle East and North Africa, a sharp drop in oil prices would be expected. But even if such events were to occur, the emerging economies would surely subsequently resume their growth, in which case any gains in production from Libya or Iraq would only buy a few more years. If the oil industry does experience another price cycle arising from such developments, any collapse in oil prices would be short-lived.

My conclusion is that hundred-dollar oil is here to stay.

Footnotes

[1] Data source: EIA (http://www.eia.gov/dnav/pet/pet_pnp_gp_dc_nus_mbblpd_m.htm).

[2] Source: EIA (http://www.eia.gov/totalenergy/data/monthly/pdf/sec13.pdf).

[3] http://www.imf.org/external/pubs/ft/weo/2014/01/weodata/index.aspx.

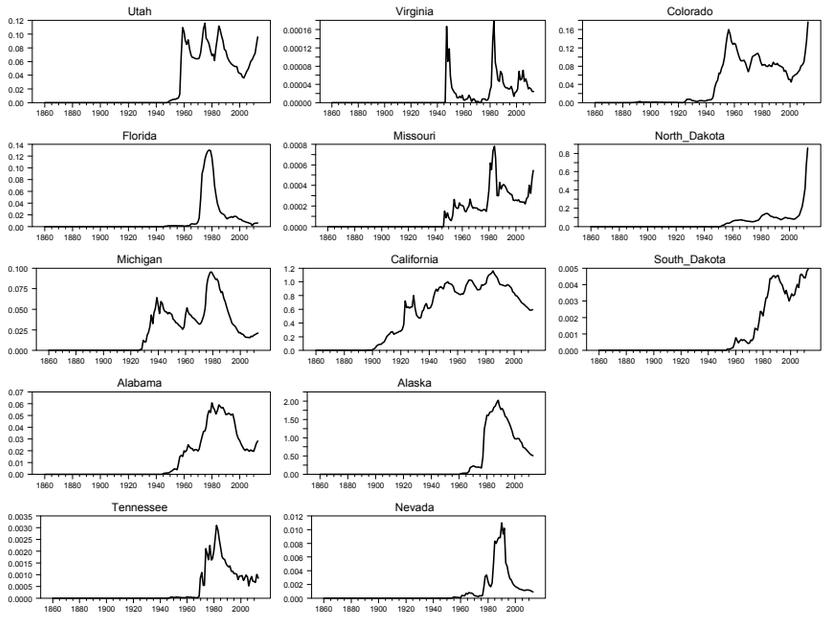

Figure 15. Annual oil production (in mb/d) from the 13 U.S. states with later peak dates. Updated from data sources detailed in Hamilton (2013)

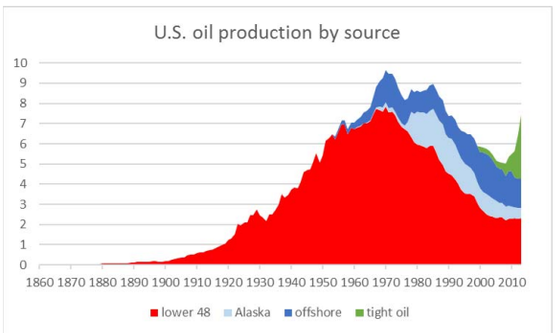

Figure 16. U.S. field production of crude oil, by source, 1860-2013, in millions of barrels per day. Data sources: Hamilton (2013) and EIA: Annual Energy Review Table 5.2; Crude Oil Production (http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm); Annual Energy Outlook 2014.

State	Date of peak
Pennsylvania	1891
Ohio	1896
West Virginia	1900
Arkansas	1925
Oklahoma	1927
New York	1937
Illinois	1940
Indiana	1953
Kansas	1956
Washington	1957
Kentucky	1959
Nebraska	1962
Arizona	1968
Montana	1968
New Mexico	1969
Mississippi	1970
Wyoming	1970
Louisiana and Gulf of Mexico	1971
Texas	1972
Utah	1975
Florida	1978
Michigan	1979
Alabama	1980
Tennessee	1982
Virginia	1983
Missouri	1984
California	1985
Alaska	1988
Nevada	1990
Colorado	2013
North Dakota	2013
South Dakota	2013
U.S. total	1970

Table 1. Year of peak crude oil field production for U.S. oil-producing states. Federal offshore production included in California and Louisiana totals. Calculated from an updated version of the database developed in Hamilton (2013).

[4] "Development of the Bakken Resource," North Dakota Department of Mineral Resources, 2014 (https://www.dmr.nd.gov/oilgas/presentations/ActivityUpdate2014-03-06ND-911MeetingBismarck.pdf).

[5] EIA, "Today in Energy," Jan 2, 2014 (http://www.eia.gov/todayinenergy/detail.cfm?id=14431).

References

Benes, Jaromir Benes, Marcelle Chauvet, Ondra Kamenik, Michael Kumhof, Douglas Laxton, Susanna Mursula, and Jack Selody (2012). "The Future of Oil: Geology versus Technology," working paper, International Monetary Fund.

Hamilton, James D. (2013). "Oil Prices, Exhaustible Resources, and Economic Growth," in Handbook of Energy and Climate Change, pp. 29-57, edited by Roger Fouquet. Cheltenham, United Kingdom: Edward Elgar Publishing.

Hill, Jason, Erik Nelson, David Tilman, Stephen Polasky, and Douglas Tiffany (2006), "Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels," Proceedings of the National Academy of Sciences, 103 (30) 11206-11210.

Kopits, Steven (2014). "Oil Demand and Growth: A Supply-Constrained View," presentation at Columbia University (http://energypolicy.columbia.edu/sites/default/files/energy/Kopits%20-%20Oil%20and%20Economic%20Growth%20%28SIPA%2C%202014%29%20-%20Presentation%20Version%5B1%5D.pdf).

Maugeri, Leonardo (2012). "Oil: The Next Revolution," working paper, Harvard University.

Sandrea, Ivan (2014). "U.S. Shale Gas and Tight Oil Industry Performance," working paper, Oxford Institute for Energy Studies.

Wisener, Robert (2014). "Ethanol Usage Projections & Corn Balance Sheet," Agricultural Marketing Resource Center, (https://www.extension.iastate.edu/agdm/crops/outlook/cornbalancesheet.pdf).