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The US shale energy boom and the price of fossil energy

美国页岩能热潮和化石能源价格

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Abstract – **This paper describes the birth of the US shale energy boom and its implications for the US and global fossil energy prices. The substantial rise in US shale energy production has been spurred by two major changes in energy markets. First, a strong rise in energy demand in emerging markets and particularly in China lifted the real prices of fossil energy to record highs in the early 2000s. Second, hydraulic fracturing began to be used in conjunction with horizontal drilling, which increased the productivity of energy extraction from shale formations markedly. The most visible impacts of the boom in fossil prices were seen in declines of the US crude oil and natural gas prices in relation to their international counterparts due to limited arbitrage opportunities between domestic and international markets. The indirect impacts on world fossil energy prices have come indirectly through a decrease in US imports of natural gas and a decrease in US imports of crude oil combined with higher oil product exports and exports of coal.**

Keywords – **shale, gas, crude oil, price**

I. INTRODUCTION

Global energy markets were transformed substantially in the early 2000s as China developed rapidly into one of the key economies in the world. This rise, supported by the other emerging markets, generated such a strong increase in energy demand that fossil energy markets could be balanced only by historically strong price rises [1].

The price of oil peaked in June 3 2008 at almost 150 dollars per barrel, which is 5.1-fold higher than in 2000. However, the real price of crude oil was, on average, nearly 2.5-fold higher in 2008 than in 2000.

The US natural gas and the Australian thermal coal prices peaked in October 2005 and July 2009 at 13.52 USD/mmbtu and 180 USD dollars per tonne, respectively. The huge nominal price rises implied also strong real energy prices – i.e. energy prices deflated by manufactured goods' export prices. The real prices of crude oil, natural gas and coal rose by 2.7-, 1.9-, and 3.7-fold up to their peaks from the year 2000. In 2013, crude oil (Brent) and thermal coal real prices were still 2.7- and 2.4-fold higher compared to prices in 2000. The real price of the US natural gas was, however, decreased to only 65 per cent of the price in the year 2000 [2] [3].

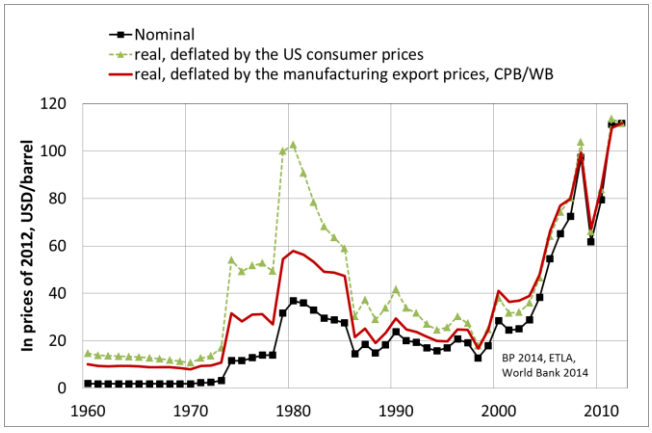

Fig.1, Real and nominal prices of crude oil (Brent)

The price rise of crude oil and natural gas in 2000-2007 was a necessary condition for the strong rise of shale production especially after 2008. Shale production took place already before the energy price rise, but in very small quantities. Rising prices and advances in drilling technology turned previously large, but unprofitable shale energy resources into profitable reserves [1]. Hydraulic fracturing combined with horizontal drilling – fracking – gives producers access to more shale oil or shale gas from relatively thin horizontal shale deposits.

There are also a number of other US-specific reasons why the shale energy boom started precisely in the US and in its neighbour Canada. Favourable geology, private land and mineral rights ownership, market structure, water availability, and pipeline infrastructure among others made the rapid rise in production possible [4].

Shale energy production is, however, expensive. The average break-even price of shale oil varies between US40/bbl –US90/bbl by resource plays [5]. The average break-even price for the shale gas production varies between $4-5/mmbtu for the key plays [6]. Prices of WTI and natural gas were US102.1/bbl and 4.36 mmbtu (or per mcf) in April 2014. Shale oil is profitable with current oil prices. The case of natural gas is more complicated as much of the production is unprofitable at current prices [4].

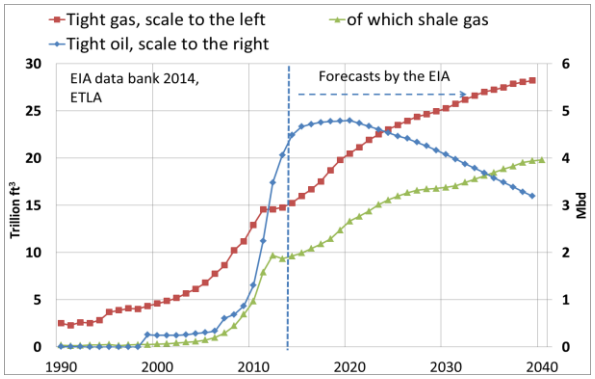

Fig.2, Tight energy production in the US

Shale energy production, i.e., tight oil production and shale gas production, picked up in the early 2000s in the US as a delayed supply response to the strong rise of the crude oil and natural gas as shown in Fig 1 and Fig 2. In this paper, we use the term 'tight oil' instead of 'shale oil' due to the statistical practice of the Energy Information Administration (EIA). The US tight oil is to a large extent shale oil, but shale gas is a separate statistical class.

TABLE 1, US SHALE ENERGY PRODUCTION

	Tight oil	Shale gas
Year	% of total crude oil production	% of total gas production
2000	4.5	1.7
2007	6.7	7.9
2008	12.3	9.8
2013	45.0	38.7
2040	42.8	52.8
Total 2013	3.48 mbd	9.35 trillion ft^3
EIA 2014, ETLA		

In 2013, the US tight oil production rose 10.2- and shale gas production 6.1-fold since 2007. The production shares of total oil and gas production of their respective total production rose to 45 and 38.7 per cent in 2013 from 6.7 and 7.9 per cent in 2007. The US technically recoverable oil and gas reserves rose by 35 and 38 per cent by the addition of tight oil and shale gas resources. [7], [8].

The shale boom has affected the US coal production indirectly due to a significant decrease of the price of gas. An increase of the relative price of coal to natural gas has led to a substitution of gas for coal in energy-consuming electricity, transportation and industrial sectors [9]. As result, the US coal exports doubled between 2007 and 2013.

These developments do not come without costs. Shale energy production techniques are not environment-friendly, which has raised a strong opposition to both production of unconventional fossil fuels and improving their logistics (e.g. the Keystone (pipeline) Project).

II. US FOSSIL ENERGY PRICES STRONGLY AFFECTED BY SHALE ENERGY BOOM

The strong rise of production which took place in the US had a strong impact on the US oil and gas prices. The strict regulation of oil exports with a mismatch between domestic crude oil demand and supply and a lack of gas export capacity, together with a substantial rise in production, led to the overproduction in the US oil and gas markets.

The export ban of oil and gas was set in response to the oil crisis in the 1970s. The ban included countries which did not have a free trade agreement with the US. Export licensing of crude oil and especially that of natural gas are currently in the process of liberalization [10].

The US natural gas prices declined strongly in response to the very rapid rise of shale gas production Fig. 4. As a result imports also declined strongly, which has been over-compensated by the increase in domestic shale energy.

Natural gas obtained from the earth is a mixture of different hydro carbon gases, water, sand and some other minor elements. Natural gas containing primarily methane is called dry gas, while the liquefiable hydrocarbon portion is called wet gas.

The mechanics of the price development of the dry gas (Henry hub) base to a large extent on the joint production of methane and other hydro carbons. The prices of natural gas liquids (NGL) have traditionally been linked to crude oil, which has resulted in a significant price premium over pipeline-quality dry natural gas. In recent years, the relatively high value of NGLs has led producers to target wet gas, which has pushed the supply of dry gas upwards and its price downwards [11]. In addition, the dry gas producers obviously continue production in anticipation of better times [12].

The main US oils West Texas Intermediate (WTI), a marker for the US Midcontinent market, and Light Louisiana Sweet (LLS) in the Gulf coast are close substitutes for crude oil from Dubai and the global benchmark Brent. Before the shale energy boom, the price differences between these oils used to

stay close to each other with relatively small quality-based differences.

The usual price relations of the key crude oils changed markedly in response to rapidly rising US shale oil output and rising imports from Canada, which exports most of its oil and gas to the US. Before the shale boom, pipelines were usually built to carry the crude oil to Cushing in the midcontinent, but now there is a need to move the expanding shale oil flows to Gulf coast refineries.

Storage capacity and pipeline capacity were inadequate to swallow rising oil flows to land-locked Cushing, an important oil hub in the midcontinent. As result, an oversupply pushed the price of WTI to deviate from Brent and from the coastal price of the US LLS in the beginning of 2011. The price of LLS followed the price of Brent until the pipeline capacity was expanded to the Gulf coast after summer 2013 and in early 2014. Fig. 3, [13].

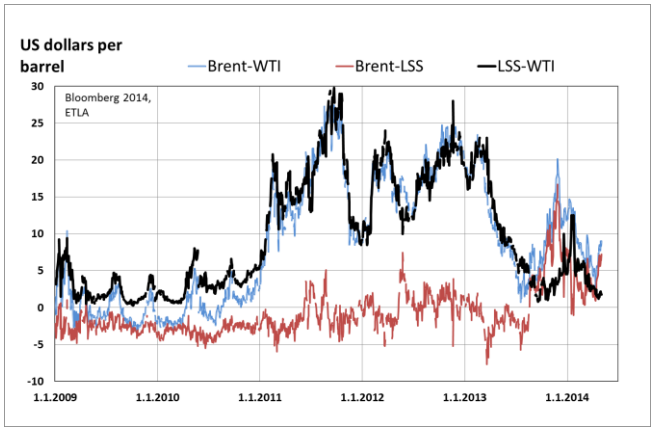

Fig.3, Brent, WTI and LLS price spreads

New transport capacity and reversals of the flows of some other pipelines to the Gulf coast shifted part of the oversupply to the coast in autumn 2013. As a result, the price differences of the US crude oils LLS and WTI were smoothened due to arbitrage and now both US prices deviated from the price of the world market benchmark Brent. This can be clearly seen in the evolution of price spreads of WTI and LLS crude oils in relation to the Brent crude. Fig. 3.

Strong decline of crude oil imports by 23 per cent from 2008 to 2013 was not able to counter the greater supply, which kept the markets oversupplied and the US prices from time to time well below the price of Brent.

The price development of the crude oil in the US is driven by the rising supply, given the decrease of imports and the demand from the US refineries for the exports of oil products and the effective export ban. The US refineries have a rather fixed configuration for the use of heavy imported oils, which restricts the decreases of imports and limits the use of domestic light oil. The US refineries have, however, benefitted from the difference of low US crude oil price and the high world market price of oil products as product exports are not banned. Exports are encouraged by implied "extra" benefits, first for the midcontinent refineries and later, once the US prices were arbitraged close to each other, also for the other refineries.

A strong rise of the US coal exports, enabled by the substitution of gas for coal, is driven by a divergence of the US coal prices from gas prices since 2005. Fig 4. As a result, the US consumption has declined by 18 per cent in 2007-2013.

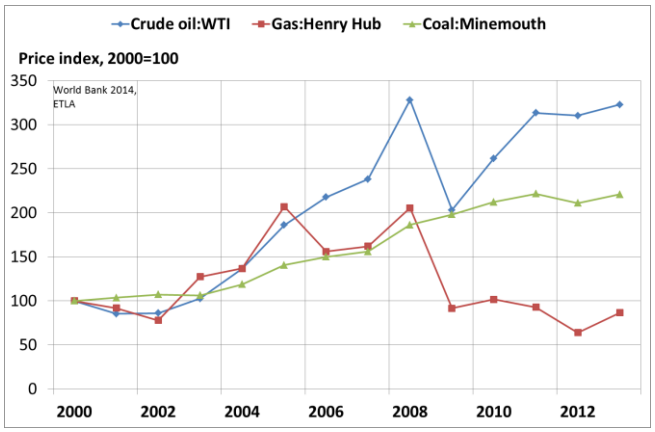

Fig 4, US fossil energy prices in the 2000's

III. International implications

The US shale energy boom took place after the dramatic price rise of global energy prices in the early 2000s. It is a good example of a reaction of global energy markets to higher prices. A supply reaction took place with a lag as oil finding, exploring and building of new sites is expensive and time-consuming. In addition, the oil producers were first cautious as the marginal costs of production in shale energy production are much higher than in conventional production.

A replication of the US shale boom is very tempting also globally as there are vast technically recoverable shale resources all across the world. The sizes of technically and economically recoverable so-called proven reserves have been estimated so far only in the US, where they cover 22 per cent of the US total crude oil proven reserves. The largest shale oil resources exist in Russia, the US, China, Argentina and Canada. The largest shale gas resources exist in China, Argentina, Algeria and the US [7] [14].

Commercially viable shale energy production, however, takes place so far notably only in the US and Canada. In China there is already some economically feasible shale gas production, but elsewhere shale energy production is mostly in a test phase. In Europe, France and Poland have the largest shale gas resources. France has, however, so far banned production due to environmental reasons, while the Polish production is still in a test phase. The main obstacle, in addition to the environmental reasons, is obviously the markedly higher marginal cost of production than in the US due to less favourable production conditions [15] [1].

So far it is the US and Canadian production which shapes the US and global energy markets. Canada is dependent on the US markets as most of its energy is exported to the US. The link between the US markets and world markets is indirect, however, as the price arbitrage is limited. Instead, a strong rise in US shale energy production affects international fossil energy prices through a decrease of the US crude oil and natural gas imports, an increase of US exports of oil products and a rise in coal exports.

Fig. 5 illustrates the evolution of world market prices of fossil energy in the 2000s. Brent crude, considered as a world benchmark, incurs downward pressure from the decrease in the US crude oil imports and higher crude oil product exports. The effect has not been strong enough to trigger a marked decrease in global oil prices. Instead the world market price of crude oil (Brent) has been remarkably stable as well since spring 2011 in spite of significant supply problems, e.g., in Iraq, Libya and Nigeria in recent years. Even the escalation of the Ukrainian crisis had only an insignificant effect on the price in spite of its potentially large effects. One of the main reasons behind the stability of the oil world market prices of crude oil is the strong rise of shale oil production in the US.

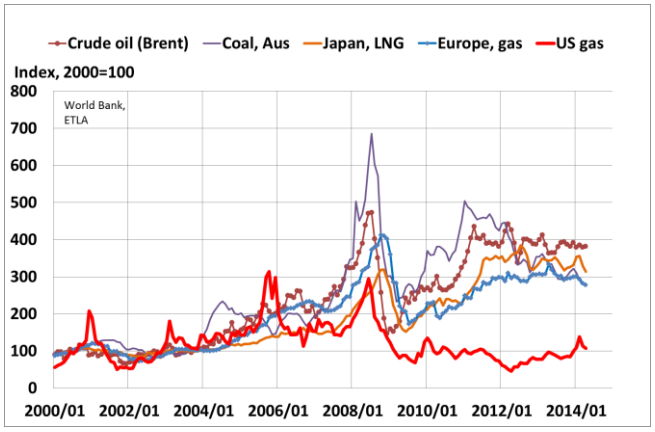

Fig 5. World energy prices in US dollars, indices, 2000=100

Obviously, in addition to the stabilization of oil prices, the shale boom, given a moderate supply policy of OPEC, has prevented a potentially sharp rise of oil prices, sparked by the recent supply problems [16].

A link between the US shale gas boom and the world markets is similar to the case of crude oil. The impact on the global markets has so far come only through rapidly decreasing imports. The global gas markets are fragmented by continent and the prices in Asia, Europe and in the US are weakly linked with a rather modest natural gas liquids (LNG) trade. The US LNG exports have been close to zero, while LNG and pipeline imports have decreased by close to 90 per cent between 2007 and 2013. Consequently, the world market share of the US LNG imports decreased to 1.5 per cent by 2012 [8] [2].

Weak world trade linkages between the continents have resulted in large price differences between the US, European and Japanese gas prices as shown in Fig. 5. In April 2014, the European import price (average) and Japanese (LNG) import price of gas prices were 2.3- and 3.2-fold higher compared with the US natural gas prices. The large differences will decline, but they are about to be rather persistent as a potentially strong increase in US export capacity is still underway and large transport costs between the continents will limit the convergence. In Europe, the average price is partly determined by the oil-linked gas from Russia.

The liberalization of the US crude oil and natural gas exports is in progress. By spring 2014, the US Department of Energy had approved five natural gas export applications and 24 more applications were in the pipeline to export gas to countries without a free trade agreement with the US. A liberalization of the US crude oil exports is still under discussion.

The liberalization of both the natural gas and crude oil exports would help in lowering the world prices of gas and crude oil. At the same time, it would obviously also raise the US prices. The liberalization would bring benefits for the US gas and crude oil producers and higher costs to the consumers, which makes decision-making politically difficult. The low profitability of gas producers and the mismatch of supply and demand of crude oil qualities - overproduction of light shale oil and a need to import heavy oil - and a potential threat of WTO procedures are pointing to more liberal policies.

IV. Conclusions

The US shale energy boom can be interpreted as a lagged supply response to the substantially higher energy prices of the early 2000s. A strong price rise together with a productive combination of horizontal drilling and hydraulic fracturing made shale oil and gas production profitable. The replication of the boom elsewhere has strong potential and it is under investigation. It is, however, much more challenging than in the US.

The very rapid rise of production had a strong impact on US natural gas and crude oil prices, pushing prices to diverge markedly from their foreign counterparts. The arbitrage opportunities for the deviations are limited. In the case of crude oil, the deviations depend on the difficulties to decrease US imports due to a mismatch of domestic supply and demand of crude oil qualities and the effective ban of crude oil exports.

In the case of natural gas, decreasing imports dampens the demand on the world markets, but exports to the world markets have been practically non-existent due to export controls and lack of LNG export terminals.

The substitution of cheap gas for relatively expensive coal has led to a strong rise of coal exports to alleviate coal demand outside the US.

The next move relating to the shale gas boom which affects world market prices is a relaxing of the US export controls of crude oil and natural gas. A number of licenses have already

been granted for gas exports. The effect will be seen later in full as export terminals are under construction. Also, the liberalization of crude oil export policy is under debate.

A rise of the US shale energy production and a successful liberalisation of the US energy trade will help in stabilizing the world price of energy. As a side effect, it will in a longer-run decrease the European dependency on the unreliable Russian energy supplies.

Energy will, however, stay expensive given the high marginal cost of shale energy, if the energy demand from China continues to grow and there will be no long-lasting stagnation in the world economy.

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