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Book review: The Natural Gas Revolution, by Robert W. Kolb, Pearson, 2014.

Robert Kolb has written a very readable book. It contains an overwhelming amount of information about the world energy market; the current status of energy reserves, production, hydraulic fracturing, horizontal drilling and use of all kind of energy, future trends, but also the history of the energy market.

The most interesting parts deal with the shale gas revolution, in particular in the United States. This revolution, together with the shale oil revolution, could mean that "the United States stands on the brink of achieving the holy grail of energy independence." If this is going to happen, even in the near future, we may soon see major changes in geopolitics and in energy prices.

The Middle East and the Persian Gulf will become less important, in particular to the United States. However, the Middle East will still be one of the most important energy regions in the world. Historically we associate the Middle East with oil export, but recently the region has also been a world leader in the export of gas (LNG). According to Kolb, Qatar is now the world leader in the export of LNG. The sudden rise in the Qatar export over the last ten years is due to the financing of Japan, which by now is the principal customer of natural gas from Qatar.

The shale gas and shale oil revolution, now taking place in the United States may reduce energy prices and change the mix of energy consumption in the United States, but also elsewhere. If other regions start producing shale gas at a large scale, Kolb points to China as the region with the largest potential, the world energy market will soon now longer be what is used to be.

For a European reader like me it is interesting to read what Kolb says about the United States and Europe: "the environmentally heedless, hydrocarbon-dependent United States enjoys cheap natural gas and falling carbon dioxide emissions, while the virtuous and environmentally conscious Europe are shunning hydraulic fracturing, closing gas-powered plants, and building coal-fired electrical capacity". Cleaner energy in the United States, and the global pollutant coal in Europe! The reason is of course price.

The shale gas revolution in the United has not only led to a switch in the energy use away from coal to gas in North-America, it has also led to lower price on coal. Wind mills and solar are on the rise in Europe, but the contribution to electricity production from these two sources are still minor. Moreover, wind and solar have to be supplemented with base load production that can either be covered by oil, gas, coal, hydropower and nuclear. The cleanest of them is hydro but the European potential is low and another CO_2 clean alternative, nuclear, is being phased out for many reasons.

Continental Europe imports natural gas from Russia, Algeria and Norway. Deliveries from Russia are not only expensive; there is also a political risk that makes these deliveries less secure. Because deliveries are expected to be more secure from Norway than from Russia the gas from Norway can be sold to Continental Europe at a higher price. This can stimulate the search for new fields in Norway and thus increase future production of gas. Although my home country has a lot of natural gas reserves, given the size of the country, it will not be able to cover a substantial part of the energy that Europe needs. Even in the environmentally conscious Europe money matters. Europe has thus turned towards coal, made cheaper by the shale gas revolution in the United States.

The LNG industry has long been dominated by long-term contracts. In these contracts the price of gas has been linked to the price of oil. Kolb argues that in a period of volatile and generally escalating oil price this pricing has become quite contentious. Kolb refer to many purchasers of natural gas who would like to move away from the long-term-oil-indexed contracts. The alternatives can be many; one that Kolb points to is that the buyers may like to transact in the spot market. May be, or may be not; the LNG industry is very capital intensive and the sellers may therefore prefer long-term contract, not necessarily linked to oil prices. Kolb's book is void of formal analysis. The emphasize is on data and history. So, let me try to add some very simplified formal analysis to the text.

Let the benefit to the seller of LNG be $\pi_s = P_g - c_g - \alpha(P_o - c_o)$. Here P_g is the unit price of LNG, c_g is unit cost, including capital costs. The last term is the opportunity costs: Instead of selling gas, the company can sell oil, and P_o is the oil price and c_o the unit cost related to oil. Prices and unit costs are all in comparable energy units. If the parameter $\alpha=1$, production of oil is the alternative to produce gas, and if $\alpha=0$, the company has no alternative to gas production. Let the cost to the buyer (a power plant) of LNG be $\pi_b = (\beta_1 P_o + \beta_2 P_c - P_g)$. Here P_c is the unit price of coal. The sum of the beta-s is 1. If $\beta_1 = 1$, then oil is the alternative to gas in the power production. If $\beta_1 = 0$, the coal is the only alternative. Of course, both beta-s could be positive, but summing to 1. If the company operates more than one plant, it may use coal in one plant and oil in another.

Assuming that the seller and buyer have equal bargaining power, a Nash-bargaining solution is obtained by maximizing the product $\pi_s \pi_b$ with respect to the price of gas. The contract price for gas will then be:

$$P_g = \frac{1}{2}\left[\alpha P_o + \beta_1 P_o + \beta_2 P_c\right] + \frac{1}{2}\left[c_g - \alpha c_o \right].$$

The traditional long-term-oil-indexed contract, where the gas seller and the gas buyer both have only oil as an alternative, follows from $\alpha = \beta_1 = 1$, which yields

$$P_g = P_o + \frac{1}{2}\left[c_g - c_o \right],$$

while a pure long-term-coal-indexed contract, where the gas seller is specialized in gas and the gas byer has coal as alternative follows from $\alpha = \beta_1 = 0$, which yields

$$P_g = \frac{1}{2} P_c + \frac{1}{2} c_g .$$

Of course a variety of long term contracts can be derived from the first formula. In the possible new energy regime, with shale gas and also shale oil production popping up in many places of the world, many different contracts may occur, not a single one. If a spot marked of gas should be realized and with many sellers so that the market becomes competitive, then $P_g = c_g$. In that case energy prices will be driven down to the benefit of the purchasers of gas. The losers will be the current high cost producers of gas and oil, for example my country Norway. Given the current problems in producing shale gas and oil outside the United States, as discussed by Kolb, I find this scenario of a competitive spot market to be less likely. Energy demand is still increasing in the world and the easy-to-find- reserves, even in the

presence of the shale gas revolution, is more or less history. I would therefore expect long-term contracts, either related to oil or other energy sources, and with some bargaining power and price margins among the producers.

A very interesting part of Kolb's book is the section concerning the potential for exports of U.S. natural gas. The rapid and strong increase in the shale gas production in the United States has raised the question of whether exports at large scale should take place. The country has already started to change infrastructure related to LNG imports into export facilities. The arguments of LNG exports is of course expected profit, but also as mentioned by Kolb, exports could replace coal in Europe and Asia (Japan) and thus contribute to global reductions in CO_2 emissions and it could also imply a geopolitical benefit. For the moment the gap between U.S and Asian prices of LNG is very, very high, but according to Kolb and others that he refer to, the costs of getting the U.S. gas to Asian users "closes much of the differential". This is of course true. But buyers in Asia and in Europe may be willing to pay a higher price for U.S. gas simply because the security of deliveries may be higher than getting the gas from the Middle East or Russia.

Kolb refer to the opponents of LNG exports who "argue that exporting gas will cause the domestic price to rise, canceling out the cost advantage that would help the U.S. economy grow and stimulate employment. For them, the key to the value of natural gas in its domestic use is its cheap price compared to the price that gas commands in other countries". Kolb also refer to an article in *Financial Times* that made the case for domestic use of gas. In the article it is argued that instead of export the U.S. energy wealth in the form of unfinished commodities it would be better to use the gas domestically to produce steel and petrochemicals, to which Americans workers have added value. Kolb does not take a stand in this debate. Let me do it. The argument by these opponents to LNG exports is completely false. If the petrochemical and steel industry is not able to pay the opportunity price of gas, i.e. the price the LNG producers can get in LNG export, the value added by the American workers in petrochemical and steel factories is negative, not positive! In this case a domestic use of gas instead of export will make the U.S. poorer not richer. We had the same discussion in Norway, both related to gas and hydropower. Fortunately, but not to begin with, the politicians followed the advice given by economists. We now have pipelines and cables to England and continental Europe in which close to 100% of our natural gas is exported and a rising share of hydropower is sent to Europe. This has definitely made Norway richer.

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