The Architecture of World Oil: a Modern Update

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Abstract

This is a paper whose first version was circulated toward the conclusion of my course on oil and gas economics at the Asian Institute of Technology (Bangkok), and shortly after the world oil price moved past ninety dollars per barrel (=$90/b) for the first time in modern history. That was in 2007, and when I gave my lecture on the Middle Eastern oil market the following year at the Ecole Normale Superieure (Paris), the price was on its way to $147/b, with predictions being made by several leading energy professionals that it would reach $200/b or more by the end of the year. What happened later that year was the beginning of a partial macroeconomic and financial market meltdown in Europe and America, as well as Japan. As explained in macroeconomics textbooks, but generally neglected elsewhere, very high oil prices can contribute to meltdowns, and this outcome in turn results in a downward pressure on the price of oil. In the present contribution I elaborate on and extend some of the discussions in my energy economics textbooks (2000, 2007). Most of this paper is non-technical, and so much (but hopefully not all) of the mathematics can be bypassed by persons who prefer to avoid symbols.

1. INTRODUCTION

When I walked into the faculty of economics at the University of Uppsala one marvellous day in October, 1973, I knew immediately that something was wrong. I didn't know whether the King had abdicated, the Third World War had started, or the national curling team had lost a match, but without talking to anyone, I was sure that somewhere a calamity had taken place. I had previously experienced a similar feeling at the University of Stockholm on the day when President Kennedy was assassinated.

The bad vibes in l973 were derived from what some people called "the Arab oil boycott". First and foremost the United States and Holland were to be taught a lesson, but other countries that in word or deed supported Israel in the latest Middle East war were also informed – directly or indirectly – that their oil supplies were in jeopardy. The exact details of the ensuing oil controversy are no longer in my memory, but one thing I remember perfectly: this is a map in a U.S. congressional document showing landing zones for marines and paratroopers in the Gulf. Professor Douglas Reynolds of the University of Alaska once informed me that a military commitment by the U.S. aimed at restoring oil deliveries was alluded to by Henry Kissinger in one of the American news magazines, which was confirmed by Dr Mamdouh G. Salameh, who added that Dr Kissenger used the expression "strangulation" when referring to the boycott. In addition he told a number of persons that this 'discomfort' could not be

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tolerated by a "great power". However when I mentioned this contingency to a so-called oil expert in Rome some years ago, she looked at me as if I had taken leave of my senses.

As far as I am concerned, good teaching begins with telling people a certain number of things they absolutely need to know, and then informing them that if they fail to get the message, they cannot obtain a passing grade. One of the things that they need to know is the possible macroeconomic and geopolitical consequences of an interruption in the flow of what is justly called the most important commodity in the world. War is one of these consequences, and an economic meltdown is another. Moreover, crude oil has a significance for the modern economy far above that suggested by a comparison of the relatively modest monetary value of oil production and/or imports with the Gross Domestic Product (GDP) of a typical oil importing country. For instance, the multi-trillion dollar economy of the U.S. rests on a very slender energy foundation. As Hillard Huntington (2007) notes, increased oil prices have a negative effect on gross domestic product (GDP) that can bring about critical losses in purchasing power

The importance of oil is largely reflected in the costly adjustments often associated with finding and introducing substitutes for that commodity, particularly in the short or medium run. In l973, in the wake of the first oil price shock, gasoline prices in the U.S. rose 40 percent, and according to Curtis Rist (1999), the ensuing panic included gutter language, threats, fights and occasional gun-play at gas stations. Here I can mention that 2013 was mentioned as the year for the global oil peak in an official or quasi-official French report that a gentleman in Paris claimed to have seen, and I once read an article by Patrick Artus – a well-known French academic turned finance professional – in which he claimed that we are steadily moving toward an oil price of more than $385/b.

Before continuing, let me say that an oil price at or near $385/b is completely off my radar, although according to Joseph Fasciani (jefasciani@highspeed plus.com) there are arguments by important researchers which claim that when environmental and military 'externalities' are taken into consideration, an 'aggregate' (or 'gross') oil price in the vicinity of $385/b is not outlandish. As for a *sustainable* $150/b oil price, that is unfortunately imaginable, though not in 2013, because if it did appear on or around that year, then the map of the oil producing zones of the Middle East that I saw in 1973 or l974 would probably reappear on a number of desks and computers in the Pentagon and similar establishments. An oil price on that level, and possibly continuing up toward the $200/b predicted by people like the late investment banker Matt Simmons, might be interpreted by some decision makers and their advisors as a declaration of war on the oil importing world.

As you may know, some very smart people now question the economics of relying on biofuels (and e.g. hydrogen and electricity) as a replacement for conventional motor-fuels. A similar position was recently taken in a long presentation in *Le Monde Diplomatique* (2007), but even so I believe that a restricted resort to less efficient and more expensive motor fuels than those derived from crude oil are preferable to an armed conflict that might drag on for years. The reason I believe this is because eventually technology and the common sense of voters will solve this problem.

The key implication here is that although it may be uneconomical just yet to attempt to replace a large fraction of conventional oil with a synthetic product, the possession by industrial countries of enough capacity to produce a few million (oil equivalent) barrels per day of e.g. biofuels in the *near* future, and slowly increasing this amount over time, might make all the economic and political sense in the world. The economic argument here is that it is often less costly to build well in advance than having to carry out a vital activity in a short period of time! The European Union (EU) wants biofuels to provide 10% of EU vehicle fuel in 2020, but employing some logic from real options theory it might be argued that it is better to be absolutely certain of at least 5% by e.g. 2012, even if for one reason or another the original

goal is later judged 'sub-optimal'. (The same reasoning applies to the U.S., where Congress has a goal of displacing 15% of projected annual gasoline use with alternative fuels by 2017.)

"*Oil will become one decisive factor in determining the new landscape of international relations*." This is the opinion of the Bundeswehr's Transformation Center, which is usually described as a German military think tank. In their analyses, the experts at that institution are quite liberal with the use of provocative terms such as "power" and 'peak oil'. "Power" is not the kind of word one expects to hear in everyday academic conversations about oil, and indeed would have been unusual in any milieu before the oil price threatened to go into orbit. When that happened President Bush began selecting his wardrobe for the trip he took to Saudi Arabia – a trip which began and ended with the Saudi king refusing to produce more oil.

As for 'peak oil', this is an expression I only use it *en-passant* in my lectures and articles, because just now it happens to be totally irrelevant. When the price of oil can reach the traumatic level it reached in June of 2008 (or $147/b), and suggestions abounded that it would continue to increase, then discussions of a global peak and its consequences involve complex psychological and political issues, as well as some intricate macroeconomics. Attempting to place these issues in a comprehensive and efficient perspective would take us outside and far beyond the simple energy economics that I am attempting to present in this paper.

2. OIL PRICES CLOSELY OBSERVED

In case readers have forgotten, one of the first modern theoretical discussions of the oil price was made by Professor Robert Solow of MIT – brilliant lecturer, Nobel Laureate, and veteran of the Second World War. His lecture (and subsequent article) was a tribute to Professor Harold Hotelling, who had died a few days earlier, and whose seminal paper on the economic theory of non-renewable resources (1931) was about to experience an astonishing revival as a result of the first oil price shock.

The theory that Professor Solow presents is touched on later in this paper, because my approach is somewhat more straightforward. In addition I use Albert Einstein's equivalence theorem to comment on the result obtained by Professors Hotelling and Solow, contending that under *realistic* assumptions the Hotelling rule is NOT the fundamental principle of natural resource economics. Put another way, what I want in my classrooms is to use ordinary profit maximization theory in an inter-temporal framework that culminates with the observation that a key variable in the analysis of oil resources is deposit pressure, and *not* – as a large part of the academic literature suggests – the interest rate. The managers of Exxon and BP are intimately acquainted with this situation, although it seems to be a mystery in most departments of economics.

This might also be the place to inform serious students of the work of Professor Stephen Salant, whose paper 'Entry Deterrence and Exhaustible Resources: OPEC versus Substitute Producers' is of the highest relevance in a world where OPEC and its very sophisticated strategy has become a pivotal element in oil market fundamentals, as I predicted in my book on oil (1980) and later publications. Salant's paper, and some of his other contributions, seem to have been overlooked as a result of the deluge of trivia received by our academic libraries, and treated with an undeserved respect.

But before undertaking an informal and quasi-formal examination of these matters, I would like to present in this and the following section a few things for serious readers to read carefully and think about, and which of course my students are kindly asked to understand perfectly. This is because, as I have found out from the forums to which I contribute, the tendency to argue about unambiguous *facts* is at least as strong as the inclination to question opinions or theories.

Five years ago I was one of the academic energy expert for the publication *Petromin*, and in one of my shorter articles informed their readers that "what we are dealing with now are not oil price shocks or spikes, but a *sustained* rise in the oil price. Thus, a shock would not begin at e.g. $25-30/b, but at least twice as much, which could result in the mother of all macroeconomic dislocations."

On the morning that was written the oil price touched $70/b, and 3 years later (May, 2008), when I was tuning up my vocal chords to lecture in Paris, it reached $130/b. I had already predicted that sand was in the machinery of the global macroeconomy, and in 2008 that machinery began to exhibit some nasty convulsions – convulsions that were instrumental in taking us to where we are today, with massive debt and unemployment problems in the industrial world.

The oil prices that I usually discuss in my work are real and unreal. The amazing thing is that some of them that were real in the past seem unreal today. For instance, in May 1999, OPEC said that they wanted $18/b for their oil, terming this price as fair for "producers and consumers". The present price of conventional oil is approximately $75/b, which has also been characterized by the energy minister of Saudi Arabia as "fair". Of course, using $P_{2010} = P_{2000}(1 + g)^t$, with 'g' the growth rate and t = 10 years, we get a value for g of about 14%. Although my position has always been that OPEC has the same right to determine their oil price as Volvo had to determine the price of the automobile they sold my wife, I might be inclined to argue that in the light of the erratic global macroeconomy, an oil price growing at a 14%t average annual rate is probably not fair for consumers or producers, where fair here is a euphemism for optimal.

Continuing with an inquiry into realism, in 1999 *The Economist* glimpsed an endless blue horizon of inexpensive oil. According to their in-house or consultant experts, the Middle East producers of oil might be better off if they let nature take its course, and allow the price of a barrel of oil to dip as low as five dollars. Five dollars was also the maximum price that Professor Milton Friedman predicted for oil during the bizarre period in which he informed his many admirers that the collapse of OPEC was a certainty. *The Economist* further suggested that nature should be assisted by those three horsemen of neo-liberal economic development: deregulation, privatization and the opening of oil fields to foreign investors. The latter was of course a completely outrageous prescription, because what it implied was that the technicians and managers of the OPEC countries were not sufficiently competent to manage their oil resources in such a way that profits and development would be maximized.

Several years later, the largest oil companies had apparently come to the conclusion that they could continue with planned operations if the oil price was $22-23/b. On the other hand, OPEC had proposed a price range in which they hoped that the oil price could be held. This was between 22 and 28 dollars per barrel. There was also the matter of a "long-run equilibrium price" for oil, which was mentioned on several occasions in a publication called *Tomorrow's Oil*, which among others had Dr Colin Campbell as an editor. As far as I could tell, this equilibrium price was somewhere around $18-20/b.

At this point let's look at an extremely useful diagram, which was provided me by one of the most important oil economists, David Cohen (2009). The thing that readers should be particularly careful to note is the sustained upward movement of the oil price after 2002-2003, because between those dates and 2008 something was taking place that probably had never been seen in the oil market in modern times. Readers should also be aware that while the price of oil fell to about $32/b when the macroeconomic bad news intensified toward the end of 2008. A number of highly credible students of the oil market – whom I will not name at the present time – then came to the conclusion that the oil price was on its way to where they thought it belonged if the laws of supply and demand – the so-called fundamentals – became valid once more. This was somewhere around the ten dollars per barrel level attained shortly

before the end of the last century. Fundamentals or not, OPEC quickly restored the situation in their favour.

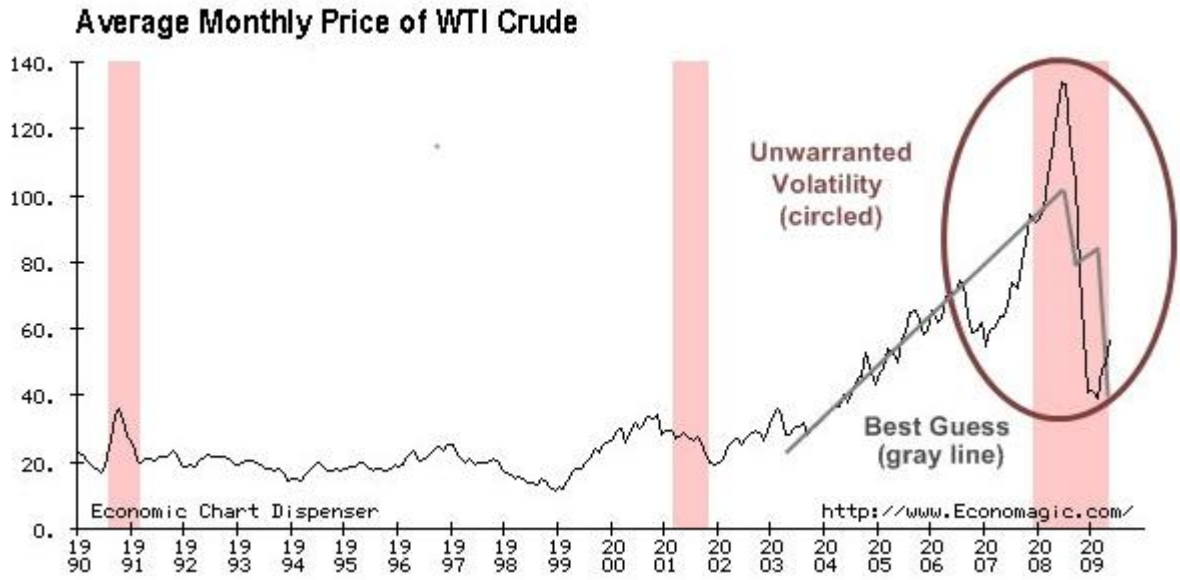

Figure 1

In this diagram we see a genuine oil price *spike* (associated with the first Gulf war), and a spike-like movement at the end of the last century, caused by OPEC cutting production by about 1,500 b/d, together with the influence on demand of cold weather in the large oil importing countries. Had the diagram been larger/wider it would have also been possible to detect the details in the conspicuous spike that took place in l973-74 as a result of the nationalization of oil by OPEC members, and also in l981, due to a change in the government of Iran. These can be compared to the sustained rise that began in 2003-04, and continued until the late autumn of 2008

One of my particularly controversial assertions is that the *most important of these occurrences was the spike-like movement at the end of the century. That demonstrated to the OPEC management what solidarity and knowledge of the oil market could accomplish in a situation where oil production was peaking in such important producing regions as the North Sea, and new large discoveries of reserves were NOT taking place.*

Then, in 2003-04, the escalating oil demand of China and India gave OPEC the opportunity they had always dreamed of, and they took advantage of it. What about speculation? In the diagram, in the background to the price movements from 1991 to the beginning of the new century, there was plenty of speculation, with smart speculators (who were usually called *traders* when they worked for investment banks) registering excellent incomes and bonuses; but from 2003 speculators – or traders as they are described on their visiting cards – did not have to be particularly smart. What they had to do to make serious money was to recognize that demand was outrunning supply, and one of the reasons for this is OPEC and its agenda becoming the determining factor on the supply side of the oil market, which is still the case!

Unlike the situation when I published my oil book, the futures market now occupies a significant role in the pricing of oil. This is not overwhelmingly important to my way of thinking, because *if the actions of speculators or /traders or dealers in physical oil have not been validated by fundamentals – i.e. supply and demand – a price movement of the steepness shown in the diagram could not possibly have taken place*! I make it my business to resolutely ignore arguments to the contrary, because neither

arguments nor algebra can convince the new chorus of hard-line populists who are resolutely determined to blame 'Wall Street' for the present macroeconomic miseries of what they call 'main street', as well as the failure of the oil price to collapse to a bargain basement value.

3. SOME ASPECTS OF IRAQ AND OIL

"The production of energy is the
moving force of world economic progress."
- Vladimir Putin

Logically, the elementary mathematics mentioned in the abstract above should be presented before this section, but much more important than a few symbols is the situation with the oil of Iraq, a country which in some circles is termed 'The New Prize'.

Recently the Swedish Oil and Gas Network graciously invited me to attend one of their important seminars, at which time I looked forward to receiving some valuable information about Iraqi oil, which is the subject of the meeting, and where I might be able to make a few friendly comments.

But I definitely needed more information, because surprisingly I knew very little about the energy resources of that country. I have a familiarity with certain aspects of Saudi Arabian oil, and I know something about economic development in the Emirates, as well as Kuwait and Qatar, but my acquaintance with Iraq was – and to a certain extent still is – distressingly inadequate. As a result I turned to the leading expert in the world on Middle East oil, Dr Mamdouh G. Salameh.

In a short paper that I received almost immediately, he told me everything about that subject that I or anybody else needs to know in order to hold their own in any seminar or conference on the face of the earth. Among other comments, his paper features the following: "If Saudi Arabia is floating on a sea of oil, Iraq is floating on a Pacific Ocean of that commodity". This is a very important piece of information, and I consider it amazing that it escaped my attention for so many years, or perhaps decades, because my book on oil was published in l980, and it contained no mention of that state of affairs. Dr Salameh also provided some statistics which brought up to date the materials in his very informative book '*Over a Barrel'* (2004).

When I read the sentence given above, I thought back to the discussion following my lecture at the Ecole Normale Superieure (Paris) in 2008, as well as the statement about the war in Iraq made by Alan Greenspan in his book '*The Age of Turbulence*' (2007). Dr Greenspan stated flatly that the war in Iraq was initially about oil, and in my lecture I contended that if anyone knows anything useful about the background to what was taking place in Iraq it should be the former head of the U.S. Central Bank, because in addition to being very smart, he was privy to some of the best scientific and economics information in the world. Just as important, over the years he has been entertained with some of the most knowledgeable gossip.

The thing to be especially appreciated is that while a war to obtain the few buckets of oil dredged from the waters near Denmark could be described as meaningless and grotesque, access to a 'Pacific Ocean of oil' might seem to a few half-baked but career conscious decision makers as well worth a war or two. I'm thinking of someone like the former Prime Minister of England, Mr Tony Blair, described by Paul Neville-Hill as a former lawyer, turned politician, turned warmonger, turned millionaire-businessman.

There are many numbers being circulated about the amount of oil that could be produced in Iraq in the present decade. The largest (and most unrealistic) that I have seen is 12 million barrels per day (= 12 mb/d), about 2020 , and the smallest (7 mb/d) at the same time. This is

hardly the place for a discussion of reserve-production ratios, but given the reserve figures provided by Dr Salameh for Iraq's oil (330 billion barrels, to include "semi-proved" and "probable" resources), the actual oil production of that country might eventually be capable of matching the actual – though not the mythical – future oil production of Saudi Arabia. (The actual will be about ten million barrels a day, plus several million 'surge capacity', where the latter is capacity that can be used over a short period. As for the mythical, this is much larger.) This point is crucial, and will be taken up at great length in the next edition of my last textbook (which supposedly is due at some time next year, or perhaps that should be in the next century). Something else worth remembering is that for most if not all of the oil producing countries in the Middle East, the difference between production and exports is bound to increase due to increases in domestic consumption.

Before continuing, something of considerable relevance should be mentioned here. Professor (of physics) Kjell Aleklett of Uppsala University sent me a mail saying that most of the oil mentioned above consisted of 'oil in place', and actual reserves came to a little over one-third of the 330 billion barrels Dr. Salameh noted. As far as I am concerned, "semi-proved" and "probably" can be lumped into 'hypothetical reserves', and NOT oil in place. (My oil book (1980) went into that concept in detail.)

Moreover, it should never be overlooked that the oil in Iraq is very often referred to as 'The New Prize', especially by genuine students of that region. Before the present weakening of the global macroeconomy, which decreased the demand for oil, some students of Gulf oil claimed that a peaking of oil in that region was inevitable in the coming decade, although I am not aware of anyone saying that Iraqi oil output would soon peak. The thing to focus on here is the often expressed conviction that there is still a great deal of oil to be discovered in Iraq, as compared to a modest amount – if any – in other Gulf countries.

Many years ago I polished my brass, and shined my shoes, and left my barracks at Fort Belvoir (Virginia) to visit the Pentagon (in Arlington Virginia), where I was interviewed in response to the application I had submitted to attend Officers Candidate School. I was, quite luckily, quickly rejected, just as (some years later) I was equally fortunate to be expelled (i.e. 'boarded out') from Infantry Leadership School at Fort Ord (California) on the final day of the course. In any event, of late I have thought about various details and complications involved in making the kind of cost-benefit calculations that important people might have someday asked me to make if I had been able to impress the gentlemen examining me at the magnificent Pentagon, or for that matter in the shabby (Leadership School) structure only a few miles from the superb beach and people-watching at Carmel (California).

In the document that Dr Salameh sent me, he says that without the war in Iraq, the price of oil today might be $40-50/b instead of $75/b. The issue then becomes would the price of oil – which began a sustainable increase about 2003 – have experienced the dramatic escalation in 2008, when the oil price topped out at just over $147/b.

This is hardly the place to give a long-winded answer, since it might involve a little algebra, but I recall being told on several occasions just after the turn of the century, that the oil 'Majors' believed that an oil price of about $23/b was likely, and in addition tolerable, while OPEC was calmly intent on reaching the upper limit of a desired price range of $22-28/b. (Remember that shortly before the end of the previous century, the oil price was almost down to $10/b.) *An oil price that steadily moved in small increments to or toward $40-50/b might therefore (ex-ante) have been wish fulfilment for everybody on the supply side of the oil market, which for some rather abstract reasons suggest to me that a price of $147 could have been avoided*! Moreover, there would have been no widely quoted and disturbing discussions of the likely future oil price by prestigious observers. In those discussions, the price of $147 led to conjecture about a possible oil price of $200/b (or higher), which was interpreted by

some movers and shakers – particularly in the financial markets – as a prelude to the end of the world.

That leads to another theme I intend to discuss at some length in the next edition of my textbook. I am speaking of whether the partial economic and financial market meltdown of 2008 would have taken place without the sustained oil price rise that accelerated in 2008. My answer is probably not, because that price escalation appears to me to have provided a cost increment (or impulse) that led to an economic downturn becoming what has sometimes been called a calamity. Certainly it has been a calamity for those individuals who would still be employed had it not taken place.

Allow me to briefly reiterate certain aspects of the above discussion. To begin, the cost of the war in Iraq is far greater than usually cited, which amounts to hundreds of billions of dollars. If correctly evaluated, it may turn out to be well over a trillion, because had the Iraqi oil industry been allowed to peacefully develop, they might have the capacity to produce e.g. 6-7 mb/d of oil now, which in turn might have galvanized ambitions to eventually produce 10-12 mb/d if sufficient reserves were available. Among other things – in theory at least – this would have helped facilitate the installation of the new energy systems/structures that will absolutely and unconditionally be required in some of the largest energy consuming countries. Energy systems in what I call the *new* energy economy, where additional nuclear will play an important role, although the emphasis should be on the *right mix* of renewables and alternatives.

In the cost-benefit analyses that were almost certainly made in the Pentagon and CIA before the second Gulf War, and which probably used *ex-post* costs and benefits from the first Gulf War as a datum, it was erroneously calculated that certain elements in the global oil picture could be altered on the cheap. The main element to which I am referring is almost certainly resolution and unity of OPEC. This is not the kind of mistake that should be encouraged if conflict or conflict-like situations evolve in the future, and particularly in brainstorming sessions in which drastic military or political measures are being considered..

Dr Salameh believes that political and economic instability will likely prevent an increase in Iraqi oil output from the present 2.50 mb/d to maybe 8-10 mb/d by the end of the decade. (I exclude 12 mb/d from consideration, although this number will almost certainly continue to be mentioned in certain restaurants of power, especially after the cognac has gone around the table a couple of times.) I know only a modest amount about instability in that country, but after reading a brilliant article in *OilPrice.Com* by Zaid Al-Ali (2010), and another in the *Spectator* by Professor Andrew J. Bacevich (2010) – a West Point graduate and former teacher at that institution, who calls the wars in Iraq and Afghanistan "dumb" – I must conclude that there is little or no cause for optimism. What is happening in Iraq is no less than an extreme version of 'Murphy's Law', which in this case not only turns on everything going wrong that can go wrong, but doing so at an intensive pace.

There is also a theory that various decision makers in Iraq are going to pay a great deal of attention to all aspects of the Iraqi oil market, and as a result 'security' is to be greatly tightened. My humble but long military background allows me to feel comfortable with the 'lingo' used to describe adventures in the security trade, however I don't know how this will work out. I do know that in the same report there was once again talk of Iraqi oil production going to 12 mb/d, which tells me that if the people who believe in that number are involved with the aforementioned security, then there is even less reason to believe that Iraqi oil production will develop in such a way as to improve the global oil picture for consumers.

I have made it clear in my work that – *ceteris paribus* – I consider OPEC as the most important factor at the present time in determining the future oil price. This is especially true since it appears that the output of non-OPEC oil producers has peaked. I would also like to suggest that if I am correct, and the OPEC directorate believes that more money is better for

their countries than less money, then it hardly makes any difference (in the short run) what individual OPEC countries are capable of producing. As you learned in your courses in price theory, an absolute key factor for determining the market price in e.g. the (more or less) oligopolistic oil market is *aggregate production*, and after thirty years of playing counterproductive games, OPEC directors are ready and able to confront that problem in an optimal manner.

4, AN ANALYTICAL DIGRESSION

If you have studied energy economics in an orthodox classroom, then you have almost certainly seen the equation $\Delta p/p = r$, where r is an interest rate. You might also see this equation in my classroom some sweet day, only my purpose is to point out emphasize that for many reasons it is a scientific misfit. The best derivation of this equation, as well as the best discussion of its shortcomings, is probably in my textbook *Energy Economics: a Modern Introduction* (2000).

Professor Harold Hotelling (1931) derived this equation using the kind of mathematics taught at Boston Public, while Professor Robert Solow employed a more general academic approach. Professor Solow pointed out that "A pool of oil or vein of iron or deposit of copper in the ground is a capital asset to society and to its owner (in the kind of society in which such things have private owners)". This is easy to accept, and so we can go to his statement that the owners of these assets – like alert owners of most assets – are constantly asking "what have you done for me lately?" This leads naturally to the most important (theoretical) economic observation, which is that: "Asset markets can be in equilibrium only when all assets in a given risk class earn the same return, partly as current dividend and partly as capital gain."

Roughly speaking, what this is all about is that if you look around and see more appealing assets than you own, then the correct behaviour is to dump any underperforming assets in your possession and buy the others, and in terms of unsophisticated theory to do it sooner rather than later.

This kind of reasoning helps to explain why, when the oil price jumped up in 1973, and a certain oil company suddenly (and unexpectedly) found itself with some spare cash, they bought a circus instead of sending their geologists out to look for more oil (which apparently they did not think was readily available). Moreover, if your assets (and others that are similar) start behaving very badly, you might purchase or think about purchasing government bonds (since the interest rate on these bonds is a kind of universal opportunity cost, promising a return (or yield) that can always be realized if other investments are unattractive, or assets in your possession lose their enchantment have to be put on the block.

I had intended to explain all of this to a seminar organized by Professor Kjell Aleklett, but unfortunately I doubt whether that gentleman is interested in organizing any seminars in which I am given the opportunity to shine. Perhaps that is just as well, because as I make clear in the energy economics book referred to above, an oil field is a very different kind of asset from many capital assets described in Economics 101, or 201 and 301 for that matter, and it very definitely is different from most if not all financial assets. This doesn't mean that Professor Solow is mistaken, because he is not in the habit of making mistakes; but that doesn't help us very much, because his approach also leads to $\Delta p/p = r$. As explained below, Albert Einstein's equivalence theorem tells us that this is something we want to avoid.

We can proceed by obtaining the above relationship ($\Delta p/p = r$) employing an extension of the profit maximizing concept taught every beginning student between Lapland and the Capetown (South Africa) naval yard. This involves the following equation:

$$V = \sum_{t=0}^{N} (p_t q_t - c_t q_t)(1+r)^{-t} + \lambda[R - \sum_{t=0}^{N} q_t] \qquad (1)$$

In the first parenthesis we have profits in period 't', which is revenue (price time quantity, or $p_t q_t$) minus 'cost' (*average* cost times quantity, or $c_t q_t$). In the third paragraph we have the given amount of the resource (e.g. oil), R, at the beginning of the period designated t = 0, distributed over N periods ($q_1 + q_2 + \ldots + q_N \leq R$). The second parenthesis, $(1+r)^{-t}$, merely discounts the profit in period 't': profits in distant periods have less value than those of the same amount in earlier periods. In conventional presentations N is taken as given, and in the Hotelling article (and many others) 'c_t' is regarded as a constant (e.g. c) that is equal to both average and marginal cost for the N periods. Furthermore 'p_t' is the *expected* price for the period 't', (although the actual price for t = 0), and the implicit assumption is that these prices as well as the amount of the resource (R) are correctly forecast at the beginning of the current period. λ is a Lagrangian multiplier, and gives us the scarcity value of the resource: e.g. it is zero if R exceeds the amount of the resource extracted during the N periods (because then the resource is not scarce).

Using the restrictions mentioned in the previous paragraph, we can now obtain the Hotelling and Solow result from equation (1). What we do is to differentiate V with respect to the values of q_t, and manipulating slightly, we obtain $\Delta p/p = r$ for successive periods. Please note though that p here is defined as the 'net' price, or price minus the marginal cost ($p_t - c$), and this net price increases at the rate r.

We go from here to Einstein's 'equivalence theorem' (or 'principle'): If two phenomena display equivalent effects (e.g. $\Delta p/p = r$), then they must be manifestations of the same fundamental laws. But as the directors of BP and Exxon might explain to you if they feel like it – c_t is NOT constant and equal to the marginal cost for *real world* oil deposits. Instead, as every petroleum engineer knows, deposit pressure decreases and (*ceteris paribus*) costs tend to increase as cumulative output increases, where by costs I am specifically referring to average and marginal costs (as well as total costs). Accordingly, in these circumstances, we do not get $\Delta p/p = r$ from a real world profit maximizing exercising. Put another way, we do not have the same fundamental laws operating for both approaches, and thus mainstream economic theory tells us that when discussing real world deposits, $\Delta p/p = r$ is useless.

If e.g. you use something like a quadratic cost function, you end up with a relationship in which r is only a discount factor. I am not going to take my soapbox to the nearest street corner in order to explain this to outraged teachers of energy economics, however I can mention that in the 1980s some OPEC directors were heard to curse the Hotelling relationship for its inaccuracy. They had actually believed that in this best of all possible worlds, the oil price was going to always increase by whatever the value of r happened to be.

Can we get anything at all usable out of the Hotelling relationship, despite what I call its "limited scientific value?" If we write it out we obtain $p_{t+1} = (1 + r)p_t$, assuming that we are dealing with a two period situation (e.g. t and t+1). The p_{t+1} might be the price at the beginning of the 'next' period, and so is an estimated price. The logic here says that if the right hand side of this relationship is larger than the left hand side, then a unit of the oil should be produced now, and used to purchase a financial asset having an interest rate of r. That can be refined to mean a financial asset or e.g. a trip to Paris for lunch, or possibly a combination of the two. If the left hand side however is greater than the right hand side, then the unit in question is left in the ground, and presumably produced in a later period.

Equilibrium comes about when the two sides are equal. I discuss this at some length in my early textbook, but I don't have any particular fondness for my explanation or that of anybody else. However, I can remember talking to several Norwegian gentlemen who told me

– and correctly – that it was economically insane for Norway to continue to produce the same amount of oil as earlier when the oil price fell to $10/b – unless of course the decision makers in Norway were obtaining their lessons in energy economics from pundits in the same London wine bars frequented by experts employed by *The Economist*, and who believed that the price of oil would continue to decline. Note the expression "economically insane". Politically, holding the production constant, or for that matter raising it, might have made a certain kind of sense, particularly if Norwegian decision makers wanted to be royally wined and dined on the occasions when they visited their counterparts in the United States.

That brings us to the work of Professor Stephen Salant, which I originally intended to discuss at great length here, but will save for another occasion. Even so, something should be made clear. The paper that I mentioned earlier, 'Entry Deterrence and Exhaustible Resources: OPEC versus Substitute Producers', should ideally have been put at or close to the top of the reading list for the kind of courses that I have taught in energy economics. Why didn't I do so? The dilemma of course was that often game theory was even more poorly taught than energy economics, and an elementary knowledge of game theory is necessary to deal with that paper. I can add that because of the position that OPEC has graduated to in the global oil market, and the fact that when considering fundamentals, OPEC can never be excluded, a modicum of game theory concepts are essential when engaged in a comprehensive study of the oil market.

5. FINAL COMMENTS; SOME ASPECTS OF FUTURES MARKETS

With so much more that could be said about oil prices and their likely development, why turn to some mechanics of futures markets? The answer is that there are many very wrong beliefs about these markets in circulation. For instance, in the latest issue of *The Middle East*, (August/September 3010), the OPEC Secretary General said that " the emergence of oil as a financial asset, traded through a diversity of instruments in futures exchanges and over-the-counter markets, may have helped fuel excessive speculation to drive price movements and stir up volatility". The key word in this quote is "may", because in reality the force driving price movements during the crucial period "2003–08 was an increasing demand from Asia, together with the decision of most OPEC countries to concern themselves with their own welfare – future as well as present – instead of that of motorists in the oil importing countries.

What is needed is an applicable introduction to this topic, and here I can recommend both of my textbooks, as well as my finance book (2001). The plain truth is that students and others often refuse to understand that futures and options are very simple subjects as long as the advanced mathematics are ignored. And despite what your favourite finance teacher might have told you, almost all of the advanced mathematics is completely and totally superfluous. Furthermore, Carol Loomis, in an article in *Fortune* called 'The risk that won't go away' (March 7, 1994) claims that few people have more than a sketchy understanding of these assets (e.g. futures) anyway, and that includes what she calls "top brass" in the financial and corporate worlds.

I say *thank you* to that, and include in the ranks of those who lack understanding – or 'smarts' as they are sometimes called on Wall Street – most of her esteemed co-workers at *Fortune*, as well as many experts they cite. One of the difficulties here is that to comprehend the relation between the oil market and the financial market it is necessary to have a reasonable insight into both, and even a likely future Nobel winner in economics – Professor (of finance) Robert Schiller – is somewhat vague on the history and mechanics of the oil market, as he demonstrates in a recent article in *Forbes* (2007).

Like options and swaps, an oil futures contract is a *derivative* asset, which means that its payoff is tied to the value of some other variable, in this case *physical oil*, which is also

referred to as the *underlying* or *actuals*. (The barrels mentioned on a futures contract are often called *paper oil.)*.

Because delivery is generally an alternative (but not a necessity), a futures contract is not a fully-fledged *forward contract*, which is a contract obliging one party to buy and receive a specific commodity (or asset) for the price that is quoted at the maturity date, and another party to sell and deliver the asset. (Please note that a conventional forward market typically involves private buying and selling arrangements between identifiable buyers and sellers that call for the future delivery of a commodity.) In the classroom a futures contract is sometimes called a *standardized* forward contract, because it is traded on an *exchange* (i.e. an *auction market*) where prices are 'transparent' (i.e. visible), and where transactions are impersonal in that buyers and sellers are generally unknown to each other. The genius in futures markets is the mechanism for avoiding delivery.

Futures markets operate as follows. Against a background of speculators betting on the direction and size of oil price movements by buying and selling futures contracts, an impersonal agency can be created which permits producers, consumers, inventory holders and various transactors in physical products to reduce (i.e. hedge) undesired price risk by also buying and selling these contracts. As uncomplicated as this happens to be, there are a great many misunderstandings about this process.

One of these is the failure to realize that there is a social gain from futures trading that derives from the voluntary redistribution of risk between speculators and risk-averse dealers in physical products! In addition, despite what you may have heard or have decided to believe, futures trading usually (but perhaps not always) decreases the volatility and level of the oil price, because by facilitating the reduction of price risk, this trading encourages producers and others to carry larger inventories. By selling from or adding to these inventories, price swings can be dampened.

The success of a futures market tends to be dependent on the satisfaction of several well defined criteria. For instance, it is essential that the commodity in question (e.g. oil) can be traded in bulk, and that it is bought and sold in circumstances that cause its price to fluctuate in a random or non-systematic manner. Without the latter provision, speculators may not be attracted to the commodity, *and without fairly large-scale speculation, futures markets will not function properly.* Here it should be noted that there are many *maturities* (i.e. time to expiry) of futures contracts in an individual market (e.g. 1 month, 2 months,…,etc maturities for oil contracts), but market liquidity usually declines rapidly for contracts with a maturity of greater than 6 months, and sometimes less. Thus it was senseless to refer to oil futures contracts with a maturity of several years, as the governor of the U.S. central bank (i.e. the Federal Reserve System) once did when asked about the future supply of oil (and thus its price). The lack of liquidity of futures with long maturities should be carefully noted by all readers.

These days the *modus operandi* of speculators is known to almost everyone with access to a television set, however a few comments might still be useful. If a speculator believes that the price of oil is going to rise, then he might buy futures contracts – i.e. he goes *long*. This can be done by simply picking up a telephone and calling his broker (who in turn makes the purchase through the futures exchange). Similarly, if he believes that the price of oil is going to fall, he can call his broker and sell futures contracts (i.e. he goes *short*). Please observe that in both cases, at first remove, he is NOT dealing in physical oil. He does NOT have to be in possession of physical oil in order to sell paper oil! True, he may be in the habit of keeping a few barrels of oil in his bedroom for speculative purposes, but that is irrelevant to what we are talking about.

There are many more transactions in paper oil than in physical oil on any given day. To understand this phenomenon the reader needs to remember that futures contracts are also forward contracts, in that delivery conditions are stipulated on them relating to the movement

of a specified amount of physical oil, on or perhaps slightly after the maturity (or expiry) date of the contract, during what is called the *delivery month*. However in a viable futures market it is always possible to avoid making or taking delivery on a contract! For example, with a long contract, at any time before the contract *matures* (i.e. before the contract's expiry date), an offsetting (short) sale is made for the same amount of oil, referred to the same delivery month given on the long contract. *If e.g. Mr X opened a position by going long, he can close it by simply calling his broker and going short!* Obviously, market liquidity is the most important factor for this operation, as the reader knows from the ease with which shares (or stocks) can be purchased or sold, and which is due to the considerable liquidity in most share markets.

The evidence indicates that delivery takes place on less than ten percent of futures contracts. This is not just because of the ease of offsetting a contract, but because delivery on futures contracts are made to or from locations that are inconvenient to most transactors. If you live in Chicago, and delivery on your long contract is made to West Texas, this takes some of the joy out of opening a position for the purpose of having immediate access to the physical commodity. In addition, as outlined in my textbook, delivery can sometimes be avoided by resorting to cash settlement. For example, a contract is held until the delivery date, at which time, or shortly after, both long and short positions are closed by 'losers' making a payment to the exchange, and 'winners' receiving a payment. The important thing here is the specification, by the exchange (or its clearing house), or 'the market' of a settlement (or 'reference') price.

Before making a few comments about the hedging of price risk, there are several extremely important topics that need to be perused. These have to do with margin, 'marking to the market', and the clearing house.

The clearing house is a non-profit operation belonging to an exchange. It acts as an intermediary (or 'middleman') in transactions, while at the same time making sure that monies are routed from losers to winners. For instance, if Mr X opens a long position and the price falls instead of rises, then he owes somebody money. Similarly, if Ms Y opens a position by going short and the price falls, she has made a profit. Why is this? She starts by selling a contract for F_1, and the price falls to F_2. Her gain is then $F_1 - F_2$ (minus the broker fee).

Perhaps the main function of the clearing house is to guarantee transactions. In order to carry out this function they are involved in *marking-to-the-market*, which means that every night after the exchange closes, clearing house employees examine the transactions that took place during the day, and inform brokers (who are certified members of the exchange) of winners and losers among their clients. These brokers in turn adjust the accounts of their clients, and perhaps inform them.

Let's take the case of Mr X. Suppose that the oil price when Mr X went to bed, and after the exchange closed, was \$40/b, and he dreams that it will increase. As a result he calls his broker the next morning and instructs him to buy one contract, which always is for 1000 barrels, and therefore the cost of the contract is \$40,000. But instead of paying this forty thousand he pays his broker *margin*, which is a security deposit, and is usually between 5 and 10 percent. Suppose that it is 10 percent, which means that he must make 4000 dollars available for his broker. Essentially someone is lending him \$36,000, and we use the expression *leverage* to describe this state of affairs. (A futures market offers its participants considerable leverage.) Often this margin is already in Mr X's margin account, which is held by his broker. Suppose that at the time of the transaction the margin account of Mr X was \$5000, of which \$3500 is specified by the broker as *maintenance margin*, which is a kind of lower limit for Mr X's margin account.

Now we can examine the situation at the end of that day. Suppose the price of oil futures increases to \$41/b. Mr X's contract is marked to this amount by the clearing house, which means that his margin account (with his broker) now contains \$6000. Of course, the \$1000

profit realized that day – minus the broker's fee – can immediately be removed, which brings the margin account back to \$5,000. (*Note that just as Mr X gained \$1000 because he was long in the oil market, someone else lost the same amount because they were short. One of the beauties of this arrangement is that accounts always balance!*)

But suppose that during that day the price fell to \$38/b instead of increasing. His contract is marked to the market at \$38/b, which means that Mr X is a loser, and his broker owes the clearing house \$2000 (which will be passed to a person holding a short position). This money is in Mr X's margin account and can be transferred to the clearing house, but now Mr S's margin account is \$500 below maintenance margin. A *margin call* then goes from the broker to Mr X for \$500, and if this money is not forthcoming during the day, the broker will usually close Mr X's position in that contract by immediately selling it at the prevailing price.

Notice that the issue here is *maintenance* margin as compared to positive margin. What the broker wants to do is to make sure that if the oil price suddenly fell from \$40/b to e.g. \$34/b, and Mr X was in his favourite jazz club in Paris and unreachable, his firm would not have to pay for the total decline (\$6000) of this particular contract. Instead they would have to account for \$1000 of this decline, following which they would curse themselves for not requiring more maintenance margin. It might happen though that they had an agreement with Mr X to transfer excessive margin from other contracts the brokerage might be holding to this contract if a price decline caused margin to move below the maintenance amount (= \$3500).

Once we understand the above, and the convergence of 'paper' and physical (or 'actuals') prices, the explanation of risk avoidance (or price insurance) becomes a detail. Convergence comes about because in its absence there is arbitrage (which means the ability to realize a riskless profit). If the price on the physical market is greater than the price on the paper market, then holders of long contracts take delivery and immediately sell on the physical (or 'spot') market. This reduces the spot price. On the other hand, if the price on the physical (spot) market is less than the price on the futures market, then holders of short contracts buy spot and deliver oil. This raises the spot price. These operations can be refined somewhat, as explained in my textbook.

Now for hedging (i.e. price insurance). Suppose that Mr X must buy some oil in 30 days, and is afraid that the price will escalate. He then buys a futures contract (i.e. goes long). If the price of physical oil goes up, and there is a convergence of the physical and paper prices, then what Mr X loses on physical oil he gains on paper oil. As the reader can easily show, he has 'locked in' the price of oil. Suppose that Ms Y is producing oil but is afraid that the price will fall. She might then sell futures contracts: if the price of physical oil fell, so would the price of paper oil, and what she lost in the physical market she would gain in the paper market. She too has locked in a price.

That brings us to a short mathematical exercise touching on the famous case of MGRM, a U.S. subsidiary of one of the largest firms in Germany, Metallgesellschaft, which lost about 1.3 billion dollars in a flawed hedging project.

What MGRM did was to offer U.S. firms fixed price *forward contracts* for (physical) oil products. These forward contracts had maturities of up to 10 years, which means that MGRM was accepting a considerable price risk, however it was the theory of their management group, which included a former professor of economics, that all would be well if a hedging program was employed that involved 'rolling over' short-term contracts. This is sometimes called a 'stack hedge', or 'stack and roll', and the magic in the scheme was supposed to be injected by what is defined as *backwardation*, with current futures contracts selling at a premium to far-dated futures contracts.

Here I 'adjust' the important analysis of Charupat and Deaves [12]. At time t = 0, for example, a 3 month contract is *purchased* for a certain amount of oil or oil product, and I designate this operation $\square F^3(0)$. This contract was then *sold* at, for example, t = 2, at which

time there is still one month to go to its maturity. I designate this selling operation $+F^1(2)$. Moreover, at this time another 3 month contract was bought, which can be designated as $\square F^3(2)$, which was sold in two months (at time t = 4) and so on. If the physical item was sold forward for C(0,T) at t=0 for delivery at time T, then total *undiscounted* profit V over the period T takes the following form:

$$V = \square F^3(0) + [F^1(2) - F^3(2)] + [F^1(4) - F^3(4)] + \ldots + [F^1(T\square 1) - F^3(T\square 1)] + C(0,T) \quad (2)$$

This can immediately be written as:

$$V = \square F^3(0) + \Sigma[F^1(2t) \square F^3(2t)] + C(0,T) \quad (3)$$

To make this work the summation is from t = 1 to t = (T-1)/2. Charupat and Deaves have a closing out of one contract on the last day before the delivery month, and the purchase of a new one (i.e. rolling over the contract) the next day, but I prefer the above scheme.

The thing to notice here is that if the majority of expressions in the brackets are positive, then the profit (V) might also be positive. For a typical parenthesis to be positive then we must have $[F^1( ) - F^3( )] > 0$, which means that a near-term futures contract has a higher price than a distant contract. As noted above, this is backwardation (or inversion), and MGRM's hedging team thought that this was almost always true for oil. They were essentially correct, however 'contango' (when the opposite happens) is always possible, and in the case of MGRM it happened, and kept on happening.

Something that is often overlooked in the populist crusade against futures markets, is that that speculation offer hedgers some extremely important insurance against unpleasant price arrangements. In an efficient market speculators should expect to be rewarded for providing this service. If we consider only short hedgers (who are afraid of a price decline), then we must have $E(P_{t+n} \mid P_t) > F_{t+n}$, E is the expectation at time 't' of the price at time 't+n' of the oil to be delivered at that time. F_{t+n} is the relevant futures contract.

A useful discussion of the oil futures markets can be found in an article by Fatouh Bassam (2006). He comes to the following conclusion. "The declining liquidity of the physical base of the reference crudes, and the narrowness of the spot market, have caused many oil exporting and oil consuming countries to prefer an alternative market to derive the price of the reference crude".

This is true, although they didn't have to look any further than my earlier books, and especially my book on copper (1974), because I made it clear that based on the research I did during three years in Geneva (Switzerland) at the United Nations Commission on Trade and Development (UNCTAD), contracts for given amounts of copper, settled at the time of delivery for prices that are transparent on the copper futures markets, had much to offer – in theory at least. This was discussed extensively on a later occasion at a workshop in Paris, presided over by perhaps the most brilliant analytical development economist of the last century, the lat Professor Hollis Chenery.

A problem inevitably arises though whenever there is a very great deal of money in play, in that some very intelligent people might be tempted to manipulate prices. Can they do this? Frankly I don't know, although I suspect that for a commodity like oil, where the amount traded – both physically and in money terms – is enormous, it would take a cartel of investment banks and/or hedge funds to influence the price. I happen to believe that a cartel of this sort would be difficult or impossible to form in the industrial world, and if it was possible, concealing it from law enforcement would be difficult.

One more comment on this subject might be useful. In his article Professor Solow says that he wonders whether public policy can contribute to stability and efficiency where reserves,

technology and demand in the fairly far future is concerned. This leads him to encourage "organized futures trading in natural resource products. To be useful, futures contracts would have to be much longer-term than is usual in the futures markets that now exist." Well readers, that's the rain on our parade, because where oil is concerned, contracts tend to be illiquid after six months and sometimes less.

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