International Economics 121 (2010), p. 99-130

INTERNATIONAL ECONOMICS
ÉCONOMIE INTERNATIONALE

The petroleum market: The ongoing oil price "shock" and the next "counter-shock"

François Lescaroux[1]

Article received on Decembre 22, 2009
Accepted on May 4, 2010

Abstract. This paper documents that the oil market has a natural tendency to experience an alternation of periods of turbulence and stability because of weak price-elasticities of supply and demand, responsible for the fact that "*there is always too much or too little oil*" (Watkins, 1937). In particular, it proposes a simple "Econ 101" explanation for the surge in both the level and the volatility of oil prices over the last few years. The analysis shows that despite the 2009 global recession, there still is "*too little oil*", therefore the energy crisis is not yet over and the price should rise to new record levels in the mid-term. On the other hand, simulations provide evidence that spare capacities should be built up again in the long-term—that is, there might be "*too much oil*" again—and hence the nominal price could correct downward and enter a new steady period once sufficient investment is made.

JEL Classification: D4; E37; Q41.
Keywords: Oil Prices; Supply and Demand Equilibrium; Forecasting and Simulation.

Résumé. Cet article montre que le marché du pétrole connaît naturellement une alternance de périodes de turbulences et de stabilité due aux faibles élasticités-prix de l'offre et de la demande ; celles-ci sont responsables du fait qu' « *il y a toujours trop ou trop peu de pétrole* » (Watkins, 1937). L'article propose une explication élémentaire pour la hausse tant du niveau que de la volatilité des prix du brut au cours des années récentes. Malgré la récession de 2009, il y a toujours « *trop peu de pétrole* » ; par conséquent, le prix du pétrole devrait à moyen terme atteindre de nouveaux records. Par ailleurs, les simulations montrent que des capacités excédentaires devraient être rétablies à long terme, il y a aurait par conséquent de nouveau « *trop de pétrole* », d'où une correction à la baisse sur le prix nominal du brut, qui entrerait dans une période de stabilité, une fois réalisés les investissements nécessaires.

Classification *JEL* : D4 ; E37 ; Q41.
Mots-clefs : Prix du pétrole ; équilibre de l'offre et de la demande ; prévision et simulation.

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1. François Lescaroux, Economist, Strategy Division, GDF SUEZ (francois.lescaroux@gdfsuez.com).
This paper reports the results of research and analysis undertaken while the author was economist at IFP (Institut Français du Pétrole), Economic Studies Division.

"*We are very sorry about the trouble that volatility could cause you, but for our part we are delighted by it.*"
Amiral Gestion, presentation letter for 'Sextant Peak Oil' fund

1. Introduction

Despite the recent contraction in global energy consumption and the oil price fall associated with the ongoing economic crisis, the outlook for demand remains upward for the coming decade; on the other hand, many investment projects have been postponed or cancelled in response to the barrel price collapse at the beginning of 2009. This raises serious issues about the mid- to long-term balance of energy markets.

As for the long-term, the US Energy Information Administration has significantly raised its oil price assumptions to 2030 in its 2009 Annual Energy Outlook as "*global demand is expected to once again grow more rapidly than liquids supplies from producers outside the Organization of the Petroleum Exporting Countries (OPEC)*" after 2010. A few months earlier, the International Energy Agency (2008) had revised upward its long-term price scenario too, on the argument that more and more expensive resources will have to be produced to meet demand. Like in the early 1980s (California Energy Commission, 1997), international and national institutions anticipate a long-run rise in real oil prices.

Further, considering the mid-term issue, the IEA (2008) warned that "*there remains a real risk that under-investment will cause an oil-supply crunch*" by 2015. Such a statement is not unusual as more and more analyses have been pointing out a potential for new record prices in the next few years, even in a low-growth case (see, for example, Jesse and van der Linde, 2008, Stevens, 2008, McKinsey, 2009, Goldman Sachs, 2009). The dramatic fall from almost $150/b in July 2008 to less than $40/b a few months later has already reversed in part and it is very likely that the price will spike again in the near future.

In this context of very volatile and uncertain oil prices, the aim of this paper is to shed some light on where oil markets are heading over the mid- to long-term. Basically, our analysis and simulations suggest that the oil crisis is not yet over and prices should keep on rising in coming years, but a loosening is likely by the end of the 2010s and nominal prices could stabilize from then onward.

Section 1 recalls oil price fundamentals. Our point is to provide some historical and analytical hindsight on recent changes and future prospects, hence setting the stage for our analysis. Notably, we underline the distinction between long-term trend, mid-term cycles and short-term cycles and recall that the former basically results from the structural increase in production costs as cheap resources are depleted whereas mid-term cycles reflect the natural tendency of the oil market to pass alternately through years-long periods of turbulence and decades-long periods of stability because investment is over-adjusting. Then, we use a supply and demand equilibrium approach focused on road transportation in the Section 3 in order to evaluate how the barrel price should move in the next decades: as for the mid-term outlook, we consider supply projections and estimate the price required for balancing consumption and production, accounting for the fact that there is "*too little oil*"; turning to the long-term outlook, we assess the potential for efficiency gains and compare the resulting trend path for demand to "optimistic" and "pessimistic" supply scenarios, which shows that there might be "*too much oil*". Finally, Section 4 summarizes our results and conclusions.

2. Petroleum economics 101

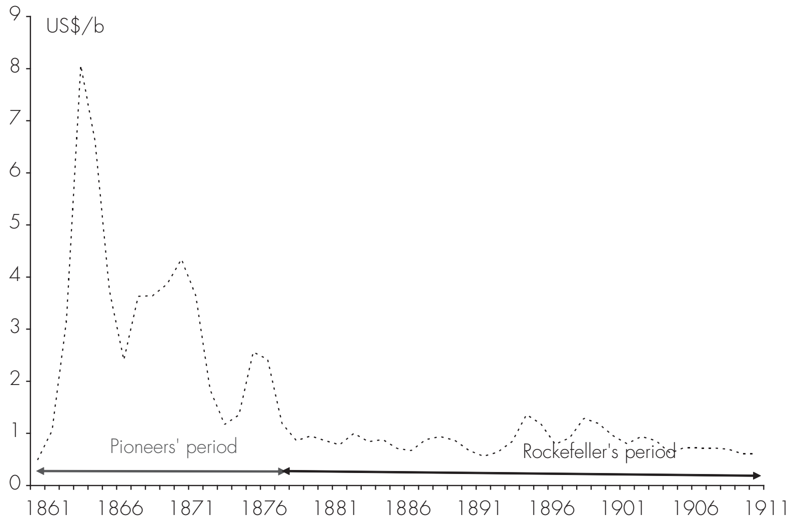
2.1 Cycles and trend in oil prices

Historically, the nominal oil price exhibits a series of long and irregular "cycles" made of two periods, one of turbulence and one of stability—a "*transient state*" and a "*steady state*" using Hubert's formulation (1974) or an *entrepreneurial* period and a *cheeseparing* one in non-physicist's terms—with periodicities varying from thirty to sixty years. Such an alternation phenomenon is a fundamental feature of the oil market that reflects long investment cycles and the succession of over- and under-capacity periods, as well as the market's natural tendency to turn into oligopoly or some other form of control during periods of excess capacity. It has been noticed a very long time ago. "*The unfortunate features of the oil industry of Pennsylvania have been repeated in the later history of almost every other producing region*" noted John Ise in 1926. "*There has been the same instability in the industry, the same recurrent or chronic over-production, the same wide fluctuations in prices, with consequent curtailment agreements.*" Earlier, Winston Churchill (1923) himself stressed that "*oil had to be bought in a monopoly-ridden market*". Some 20 years later, Paul Frankel (1946) reached the same kind of conclusion—with no value judgement. "*As there is always either too much or too little oil, the industry, not being self-adjusting, has an inherent tendency to extreme crises […]. As no individual unit can evolve a rational production policy on its own, some sort of communal organization is almost inevitable. Paradox though it may appear, oil, competitive* par excellence*, is usually controlled by some "leading interests"*." Figures 1, 2 and 3 show the three mid-term cycles experienced since the birth of the industry.

The rationale for the market to turn into some form of monopoly, oligopoly or combine when excess capacity materializes is very intuitive and has been expressed by Paul Frankel too: "*all-out competition, where it is allowed to prevail in the oil industry, leads either straight to general bankruptcy or to the monopoly of a survivor*". Indeed, as fixed costs are very high compared to variable costs, oil companies cannot resist periods of over-supply for long because the price has to drop to the short-run marginal cost in such instances. Indeed, facilities will not be shut down as long as the price level enables to pay back part of the investment and overheads. As a consequence, one producer—or a group—has to take the responsibility of managing spare capacities to remove from the market what is in excess and rebalance supply and demand at a price level that enables to pay for the investment. The constitution of some form of control in the oil market is all the more simple as low-cost reserves and production capacities are concentrated in a few countries, which makes it easier for an oligopolistic group to manage to influence the whole market by taking over these resources.[2]

Every time it happens, the oil price stabilizes at a level that *satisfices* the dominant actor's utility—the leader being limited in its decision-making by bounded rationality. Rockefeller has kept prices in a 0.7-1 US$/b band, the Seven Sisters have stayed close to $1.1/b up to 1947 and $1.8/b from then onward (see note below Figure 2) whereas OPEC has targeted a $18/b price level until the early-2000s. There is no formal reason for the optimal price to be stable in nominal terms, except that fears of a fall in sales volumes over the mid-term (because of the emergence of competitors within the oil business, the development of substitutes or investment in energy saving plans; see Tarbel, 1904, and Frankel, 1946, about Rockefeller's period, Bamberg, 1994, for a draft of Achnacarry Agreement and Yergin, 1991, on the definition of OPEC's price target in 1986) limit the potential for price increases whereas the short-term objective of returns leaves little room for price decreases. However, such a stabilization inevitably leads to a period of insufficient investment in exploration which ultimately ends in a sustained episode of high prices. In turn, the surge in oil prices induces massive investments both on the supply- and the demand-sides. As new production capacities progressively come on-stream and fuel-efficient technologies spread in society, overcapacity appears again and the oil market loosens. Once more, a competitor or a group that benefits from a decisive competitive advantage—like controlling low-cost Middle-Eastern oil resources—can set the price at a level that guarantees satisfactory revenues without jeopardizing market share by adjusting production to mirror changes in demand.

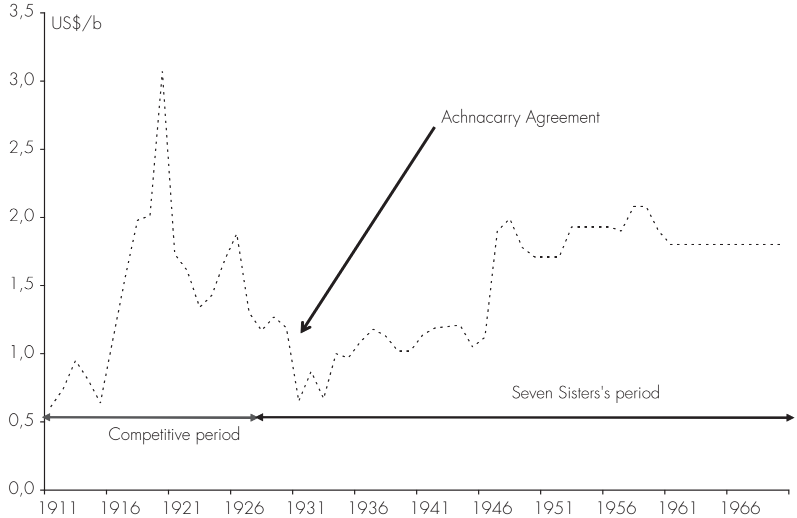
Figure 1 - First cycle



Source: Data from *BP Statistical Review* (2009).

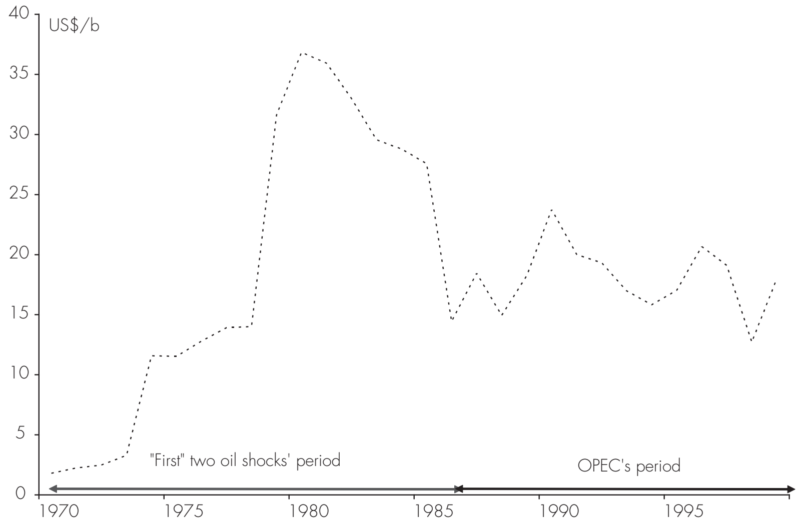
2. Nonetheless, this is not a necessary condition. As a counter-example, Rockefeller and the *Standard Oil Company* succeeded in taking control of the market thanks to competitive advantages in refining and mainly transport.

Figure 2 - Second cycle



Note: the surge in 1947 is simply the consequence of a monetary shock; there is no such step in real terms.
Source: Data from *BP Statistical Review* (2009).

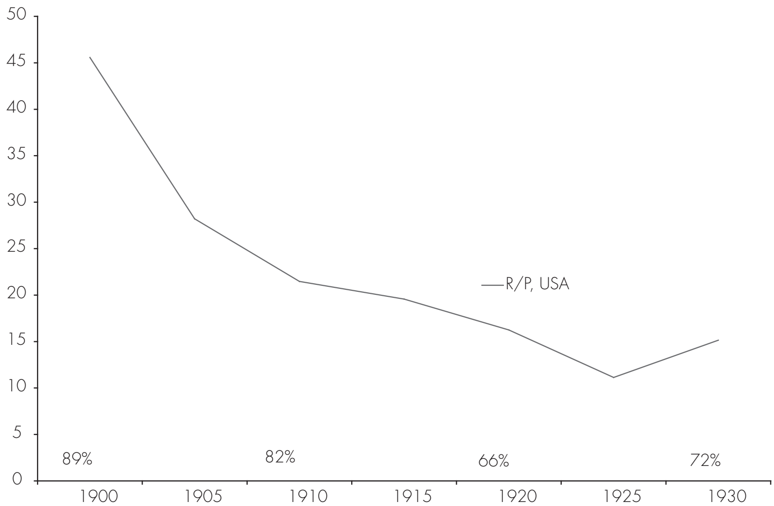
Figure 3 - Third cycle



Source: Data from *BP Statistical Review* (2009).

This alternation of under- and over-investment periods—leading to under- and over-capacity periods—may well be highlighted by changes in the ratio of 1P reserves[3] to production (R/P ratio). This parameter is a poor indicator of expected oil availability as it assumes constant prices and frozen technology (Schurr *et al.*, 1960, p. 348), and because backdated 2P reserves would be better suited to provide knowledge on what is likely to be produced in the future (Campbell and Laherrère, 1998). However, from an economic point of view, this is a useful indicator of inflection points in petroleum prices. Indeed, the R/P ratio always declines during periods of control, because a supply control is imposed at first to manage excess capacities and then because the price control eventually leads to under-investment (see Figures 4, 5 and 6). Thus, the duration of the *cheeseparing* period depends on how fast the R/P ratio goes down. When it reaches a floor, whose level is highly subjective and depends on *zeitgeist* and the current perception of scarcity, the price has to rise in order to both slow down demand (thus weighting on the denominator) and mainly to make more reserves economic (raising the numerator). As the market enters an *entrepreneurial* period of high prices, investments on the demand- and the supply-sides are made, whose effects are synthesized in the growth of the R/P ratio. Once it reaches a *reasonable* level, the price can stabilize at a *reasonable*, usually higher-than-before level.

Figure 4 - Reserves to production ratio, USA, 1900-1930

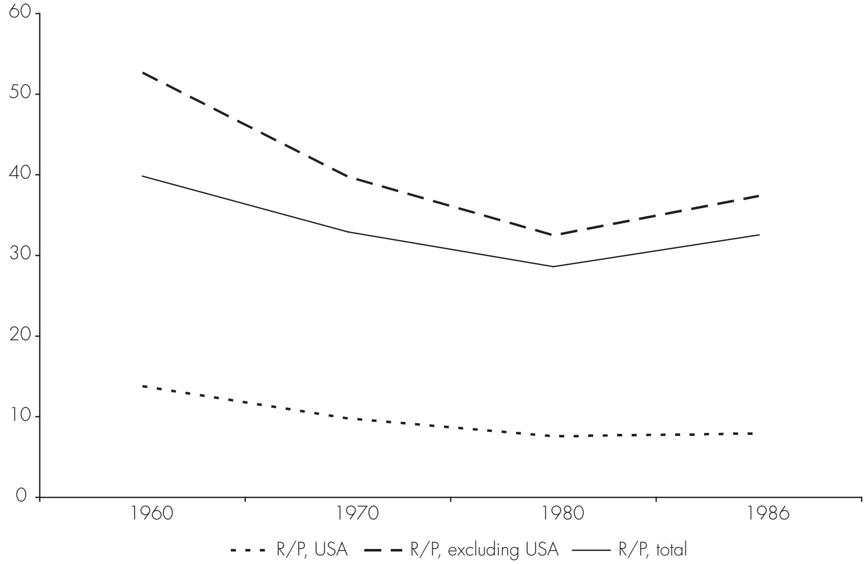


Note: Percentages refer to the share of US in global petroleum production.

Sources: Data from Schurr *et al.* (1960), Giraud and Boy de la Tour (1987) and US DOE/EIA website.

3. "Proved reserves" (or 1P reserves) are hydrocarbons that have been discovered and for which there is a 90 percent probability that they can be extracted profitably (on the basis of assumptions about costs, geology, technology, marketability and future prices). "Proved and probable reserves" (2P reserves) include additional volumes that are thought to exist in accumulations that have been discovered and that are expected to be commercial, but with only a 50 percent probability that they can be produced profitably (IEA, 2008). "Backdated reserves" are a measure of reserves that "backdates" belated revisions to individual oilfield estimates to the year in which the fields were discovered, contrary to "reported reserves" that consider the year in which the revisions occurred.

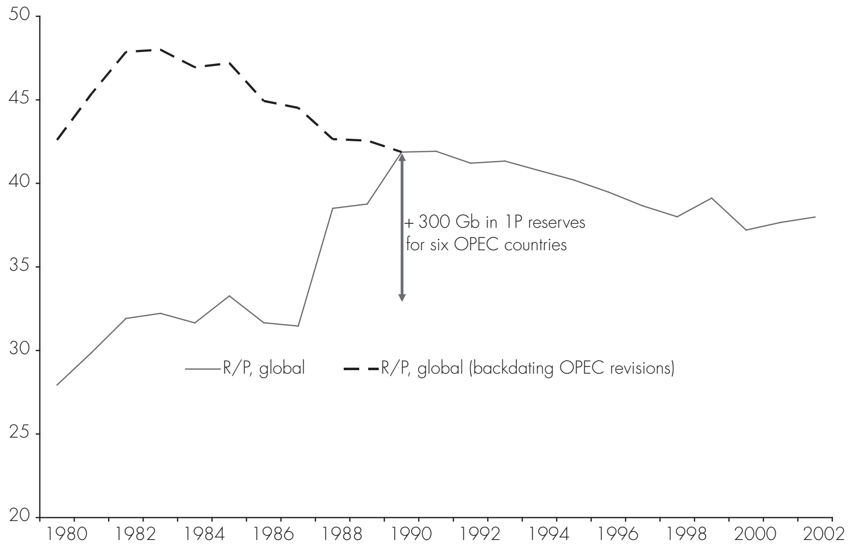
Figure 5 - Reserves to production ratio, 1960-1986



Note: USA considered separately because import quotas were isolating the US market from the global market until the early-1970s.

Sources: Data from Giraud and Boy de la Tour (1987) and Masseron (1991).

Figure 6 - Reserves to production ratio, 1980-2002



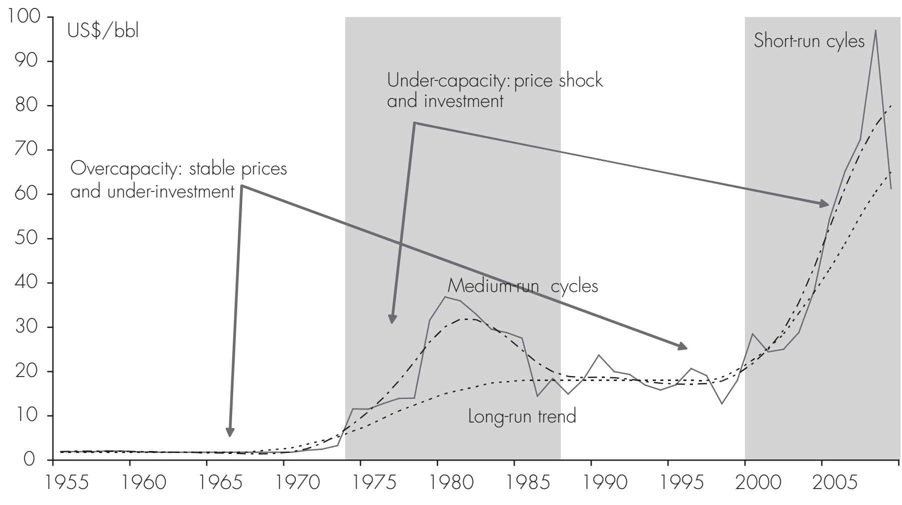
Note: Author's rough correction for dubious OPEC's reserves revisions (at a time when production quotas were affected by 1P reserves).

Sources: Data from *BP Statistical Review* (2009) and US DOE/EIA website.

Focusing on nominal oil price changes since 1955, the process may easily be observed and documented. The long-run trend evolves as a simple function: from time to time, it raises one step and then stays flat for years. Big waves form above this tendency separated by thirty years roughly. In the short-run, day-to-day and month-to-month changes in oil markets cause ups and downs around these big waves (see FIGURE 7).

Long- and mid-term changes result directly from the interaction of investment cycles and the natural tendency toward some form of control discussed above. During the 1950s and the 1960s, oil majors were fully controlling the oil market, from upstream activities to transport, refining and products distribution. They chose to keep crude prices flat in nominal terms in order to limit both the development of smaller, independent oil companies and the penetration of other energy resources, notably nuclear electricity (see for example the draft of Achnacarry Agreement in Bamberg, 1994). Consequently, they used to raise production from low-cost Middle-Eastern fields on a just-in-time basis. For 15 to 20 years, this strategy has worked perfectly well, the share of oil in primary energy supply rising to 46 percent by 1973.

Figure 7 - The oil price since 1955



Source: Data from US DOE/EIA website.

However, oil prices were too low at the beginning of the 1970s. Demand addressed to OPEC member countries rose from 6.7 million barrels per day (Mb/d) in 1960 to 20.2 Mb/d in 1970 and 27.5 Mb/d in 1973. In the face of rising consumption, the nominal rigidity of the oil price and its downward trend in constant money terms had constrained prospects for investment[4], as indicated by the continuous fall in the R/P ratio (see FIGURE 5). Supply could not keep up with demand. In the early days of the first shock, there was very little spare capacity available. In the short term, the supply was likely to be inadequate and, for the

4. The rise of nationalism in many producing countries played a great part too, as it was risky for international oil companies to invest in those countries considering the high likelihood for nationalization of petroleum resources.

first time, prices practiced on the world spot market exceeded posted prices[5], a sign that the oil market was becoming a seller's market. The East Coast of the United States was hit by a shortage of oil and gas at the beginning of 1973, while the Texas Railroad Commission —which had been assigned the task of matching oil production to demand in the US—had ended prorationing and declared a "*100* percent *crude-oil allowable*" on March 16, 1972[6] (following the peak in US oil production in 1970). In this respect, the Yom Kippur War provided an opportunity for rather than caused the shock (IFP, 2007).

In response to higher oil prices, massive efforts have been devoted by Governments in consuming countries to promote energy-saving technologies and behaviours. In Western Europe, for example, passenger cars' unit consumption (that is, the quantity of energy per kilometre or mile) has declined by 30 percent from 1970 to 2000. Moreover, oil production techniques previously uneconomic became progressively attractive, allowing for capacity development outside of OPEC member countries. Offshore techniques notably experienced a fast development. Indeed, as more and more offshore platforms were built, learning-by-doing enabled to lower installation costs and to go ever deeper and further away in open sea. New first-order producing regions appeared on the map, like the US Gulf of Mexico, the North Sea or the Gulf of Guinea. As for other energy resources, public opposition to nuclear power vanished to a large extent with higher oil prices (IEA, 1998), at least in some countries[7]; its share in primary energy supply has grown from 0.9 percent in 1973 to 6.2 percent in 2006. Gas has progressed as well, from 16.0 percent to 20.5 percent.

As a result, the market became oversupplied at the beginning of the 1980s. OPEC countries desperately tried to sustain oil prices by lowering output to excessively low levels —especially Saudi Arabia, that has been carrying most of the burden—until they changed their strategy and decided to "*secure and defend for OPEC a fair share in the world oil market consistent with the necessary income for member countries' development*" (Middle East Economic Survey, 12/16/1985) by stabilizing prices between 15 and 20 US$/b. This new equilibrium level was much higher than the one prevailing before the "first" two oil shocks: despite innovations and learning, production costs had risen to allow more complex oil resources to be produced.

Nonetheless, OPEC has succeeded in balancing the market in a nominal price-band for 10 to 15 years thanks to huge spare capacities set in the first half of the 1980s and to progresses by oil companies in production techniques. During the 1970s and the first half of the 1980s, high oil prices have induced them to find oil *at any cost* to restore market balance and they experienced new technologies to develop "frontier" resources in "frontier" areas in

5. The posted price was the price agreed upon by companies and producing countries, which was the reference used in the determination of royalties and taxes.

6. http://www.rrc.state.tx.us/about/history/chronological/chronhistory03.php.

7. In the United States, some advisors to President Nixon were favorable to a moderate increase in oil prices that would soften public opposition to nuclear power, as revealed by statements of Mr. Ehrlichman to *US News and World Report* (February, 1973); such positions may have influenced the price agreements concluded in Teheran and Tripoli at the beginning of 1971. However, the accident at the Three Mile Island plant in the US in 1979 shook up the nuclear industry worldwide and led to a slowdown in capacity addition (IAEA, 1987).

an *entrepreneurial* spirit; with the counter-shock, they turned to a *cheeseparing*[8], cost-cutting rationale (Alazard, 1996). Méo (1990) reports that a 17 percent decrease in North Sea operating costs occurred between 1986 and 1988 thanks notably to a twofold or threefold cut in services costs. This fall was a downward correction for past inflationary pressures in the oil services industry that had largely contributed to cost escalation (just like today). "*In late 1973, shortages in raw materials and components developed. The companies were bidding for a limited and fixed supply of materials and components, and their prices* "went through the ceiling." *The suppliers of these products were able to capture some of the economic rent the companies expected from their field development projects*" (Eckbo, 1977). For Canadian oil sands, operating costs declined from more than 30 (1997)US$/b to less than 10 (1997)US$/b between 1981 and 2001 (*Oil & Gas Journal*, 7/28/2003). Further, progressive learning in new production techniques (like horizontal drilling and 3-dimensional seismic surveys) and productivity gains in older ones (vertical drilling notably) enabled companies to lower exploration and development costs (Boy de la Tour, 1999, Freund, 2000). On average, they managed to cut total offshore production costs by $1/b each year from 1985 to 1995 (Appert and Boy de la Tour, 1997).

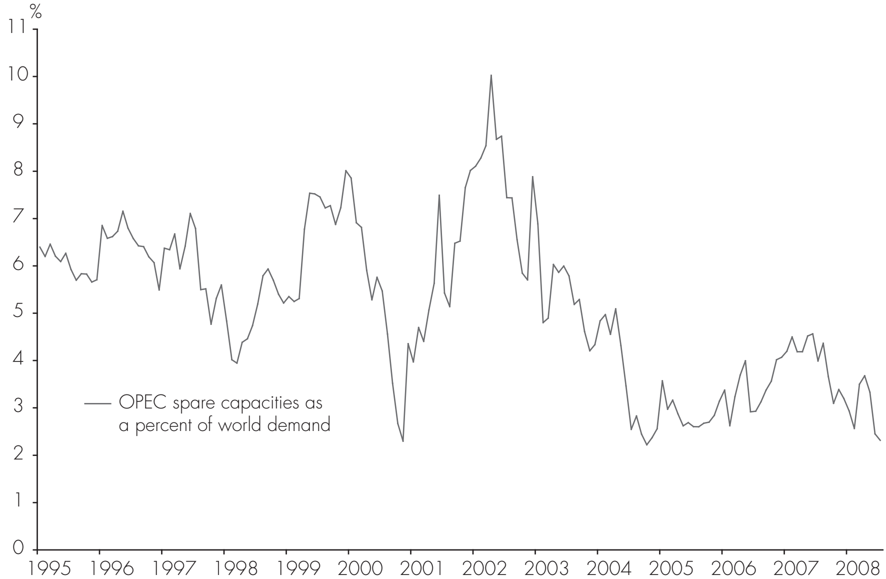
The combination of large initial spare capacities and a large potential for productivity gains explains how the long-run marginal production cost—and thus the trend in the equilibrium price during stability phases—might stay flat in nominal terms over long periods. According to Adelman (1972), prices are the result of a race between the depletion of known reserves and technical progress. As pointed out by Mabro (1992), the latter tends to run out front during the long episodes when oil resources seem abundant relative to demand.

But again, excess capacities have shrunk at the beginning of the 2000s (see FIGURE 8[9]) and a perception of rapid depletability arose again. The surge in energy demand from emerging countries has been largely unanticipated and supply simply could not keep pace with demand. Again, oil prices had to rise for demand destruction to occur—until efficiency gains in oil consumption and the development of costlier resources enable a stabilization of oil prices at a new long-term equilibrium level, likely higher than the one prevailing in the 1990s.

8. Our labeling is somehow unfair as *entrepreneurial* periods do not have a monopoly on innovations. *Cheeseparing* periods saw many innovations too, like horizontal drilling that developed between 1985 and 1995 or catalytic cracking and catalytic reforming that were invented in the 1930s. Yet, these were the results of long-lasting research efforts. Mostly, the frame of mind within the industry differs greatly from one state to the other: producers struggle to climb up along the supply curve during *entrepreneurial* periods whereas they wrestle to shift it down during *cheeseparing* ones, some of them sliding along through curtailment agreements—with all that such distinction implies in terms of business model and risk-aversion.

9. The US DOE/EIA provides different figures for OPEC's spare capacities, but the trend is the same and it does not alter the conclusion to use one source or the other.

Figure 8 - OPEC spare capacities



Source: Data from IEA.

All these mechanisms can be formalized slightly and explained with "Econ 101" drawings.

2.2. Supply, demand and price

The marginal cost of supply is the production cost of the most expensive produced resource (or the cost of the cheapest, available non-produced resource) needed to satisfy demand (or incremental demand). By ranking resources according to rising production costs, the supply cost curve plots the marginal production cost as a function of the cumulative production level.

Similarly, the marginal utility of demand is the utility of the marginal use—that is the least useful use. Again, by ranking uses according to decreasing utilities, the demand curve plots the marginal utility as a function of the cumulative consumption level.

For any good or service, the intersection of the supply and the demand curves defines the long-run market's equilibrium, which consists in a price-quantity couple.

Of course, neither demand nor supply alone sets the price, but both of them. Yet, depending on oil market's balance, one of the two curves is more flexible than the other. When there is "*too much oil*", the management of spare capacities enables the leader to easily shift the supply curve; hence, the equilibrium price is mainly determined by the marginal production cost that suits its policy. To the contrary, when there is "*too little oil*", supply is almost fully inelastic; therefore, the user value tends to drive the equilibrium price.[10]

2.3. Management of excess capacities: the oil price in periods of control

When the oil market is well-supplied and some production capacities are in excess, holders of Middle-Eastern, abundant and low-cost resources are able to set the market price by forming a cartel and adjusting their supply. They can be seen as leaders in a Stackelberg competition model.

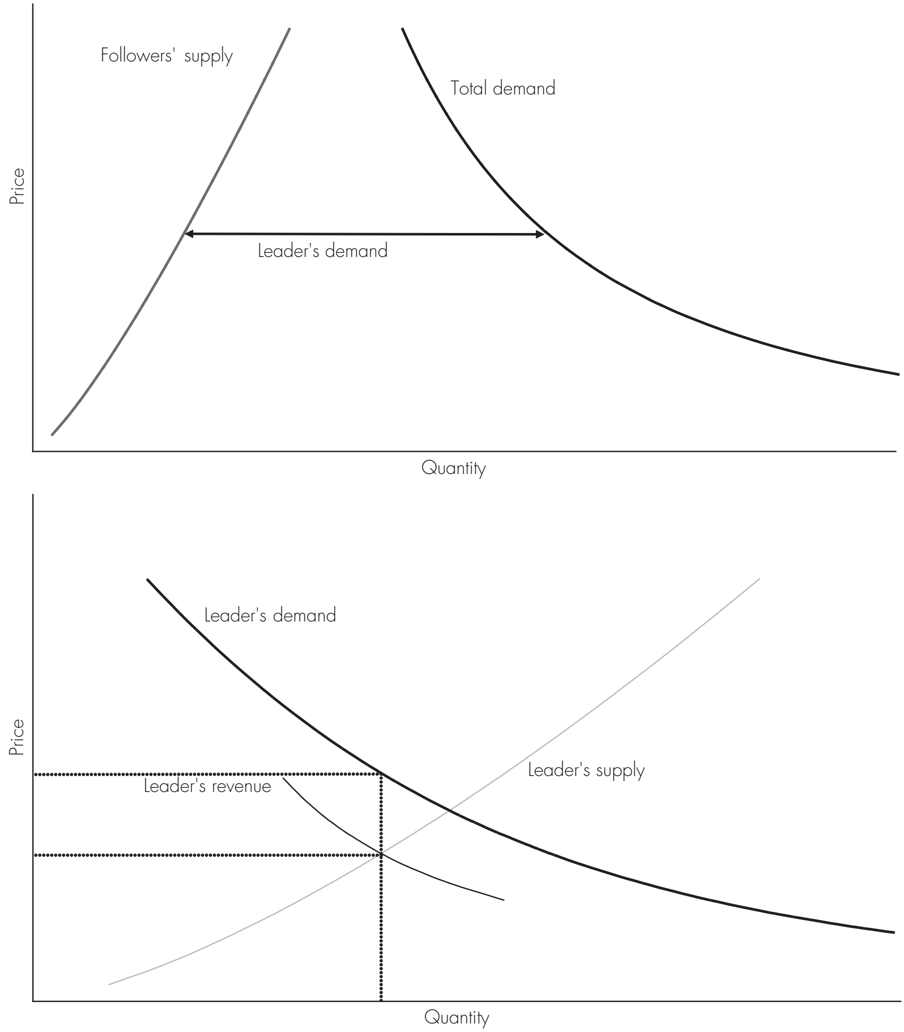
The reason is that the cartel holds a significant market share and producers outside of the cartel (the followers) cannot meet demand alone. If the oil market was fully competitive, cheapest resources would be produced first and more costly ones would be put on-stream as demand increases. Because of the oligopolistic behaviour of a group of producers, which hold the bulk of the reserves (OPEC today, major oil companies in the 1960s), this is not the case. Nonetheless, other producers, which account for more than half of world oil production, act competitively.

If the cartel knows the shape of the demand curve and the supply curve of other producers, then it can easily determine the price that maximizes its profit (quantity times market price net of production cost) and set it. In fact, it behaves as a monopoly that responds to a specific demand function, defined as the difference between total demand and supply from producers outside of the cartel (see FIGURE 9), and thus maximizes profits by producing where marginal revenue equals marginal costs: the intersection between its revenue and supply curves tells it the optimal quantity to produce. The market price is thus the value on the y-axis of the leader's demand curve for the optimal quantity on the x-axis. The difference between market price and production cost makes the monopoly rent.

Most of the time, the maximization of the price-setter's utility consists in something larger and fuzzier than just maximizing current oil revenues and various factors are considered. In fact, the problem is so complex (with some parameters difficult to quantify) that the price level is usually chosen by the leader rather than determined as the result of a true optimization exercise. As reported by Yergin (1991), OPEC "*played it by ear*" in 1986. Intertemporal arbitrages intervene. Discouraging research and development efforts on substitutes (either oil from other regions, or alternative energy resources and technology) may play a great role too. Further, some bargaining with consuming countries and other producers might occur (Mabro, 1992). This point has been crucially important at the time of the counter-shock, when OPEC countries opted for the 15-20 US$/b price-band. At the beginning of 1986,

10. Mabro (1992) puts forward that some kind of Hotelling rule may be at work during such episodes. Yet, he acknowledges that the empirical significance of Hotelling's theory is limited and that it just provides some insight. Indeed, Hotelling is much more popular in the academic world than in the business one and we doubt that buyers and sellers of crude on spot markets care about him. Consuming countries' Government may do, but official prices or official targets follow the spot price in periods of turbulence—just like futures prices.

Figure 9 - Price setting in periods of excess capacities



the price plunged below $10/b. The estimated cost for a barrel produced in Oklahoma was $13.8 then; it was more expensive in Texas (Araim, 1991). As a consequence, the economies of many states (Texas, Oklahoma, Louisiana, California, and Alaska) were badly hurt. The energy industry was damaged too. As a consequence, Vice President Georges Bush travelled to Saudi Arabia with a message that open competition had its limits in the oil market and that a certain floor price should be respected for the sake of the US oil industry (ISG, 1986). He considered that "*substantial financial institutions in this country could be hurt*" with a barrel price below $12 (New York Times, April 6, 1986)—a position that was disavowed (Noreng, 2006) by the Reagan White House whose precept was that free market would provide price stability. According to Saudis, Bush Sr. "*had explicitly issued a warning* *that the United States would impose a tariff if prices remained down*" (Yergin, 1991). Late in May 1986, six OPEC oil ministers met in Saudi Arabia and agreed on an $18/b price target. Considering all conflicting interests, such a level seemed to be a *good* choice, if not the *optimal* one. It was sufficiently low to preserve oil competitiveness against other energy resources and further conservation measures, to curb non-OPEC oil production and to stimulate economic growth worldwide—and thus oil demand[11]; on the other hand, it was high enough for not jeopardizing investments already done in energy saving plans and mostly not devastating the oil industry—including their own which funded a large part of their public budgets.

2.4. Demand and supply destruction: the oil price in periods of turbulence

The rationale is completely different in periods of excess demand, when needs outpace the maximal production level. In such situation where a lack of investment has put too low a constraint on production capacity which cannot meet consumers' needs whatever the price, the value of oil might have to rise far above the long-run marginal production cost in order to destroy demand and keep consumption in line with production (see FIGURE 10). The oil price increase encourages rational consumers to gradually limit their use of oil to those purposes where it is most useful to them. This permits an adjustment between relative price and relative marginal product.

In such situations, prices get highly volatile because the demand curve crosses the supply curve in its vertical part and small moves in the former—caused by changes in per capita income for example—deeply affect the position on the y-axis of the equilibrium point. This is the situation since the mid-2000s. Over the last few years, supply growth has lagged demand growth and the price for oil has been set by its user value, far above the marginal production cost—which incidentally has sharply increased for reasons discussed later.

By the way, FIGURE 10 enables one to understand the highly debated relationship between the US Dollar exchange rate and oil prices. Every time the greenback depreciates against other currencies, this raises the purchasing power of non-US consumers for oil and the demand curve moves to the right. But if supply does not expand, then the barrel's Dollar value has to increase for the price expressed in other currencies not to fall and demand not to increase in excess of what can be produced. Overall inflation affects oil demand and nominal price in exactly the same way. This explains why oil contracts are used by traders to hedge themselves against exchange rate and inflationary risks.

We have switched since 2008Q4 from a demand destruction situation to a supply destruction one. But symmetrically, prices have to fall far below the full, long-run production cost for operations to be shut down on any well. As long as operational costs are covered, it is

11. *Modern* oil economists have been traumatized by OPEC's policy at the beginning of the 1980s and most of them consider that cartels are formed only to raise prices as high as possible. As long as the oil industry is concerned, the primary objective is price stability (Frankel, 1946, p.81 and following). Further, successive oil cartels have never been long to learn—using Ida Tarbell's words (1904)—*"that, however great the fun and profits of making oil very dear, in the long run it does not pay; that it weakens markets and stimulates competition"*.

rational for the company to keep producing.[12] Thus, the marginal operational cost has set the price over the first months of 2009—until OPEC adjusted its quotas to restore a "fair" price level. According to a Deutsche Bank (2009) review, a very small part of total oil production has an operating cost higher than $30/b. This explains the fall from almost $150/b in July 2008 to less than $40/b a few months later (see FIGURE 11).

Figure 10 - Price setting in periods of constrained supply

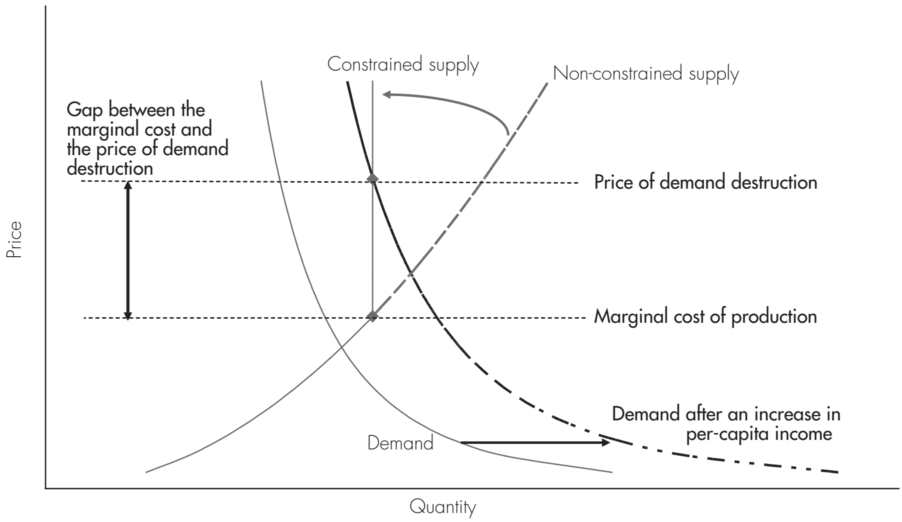
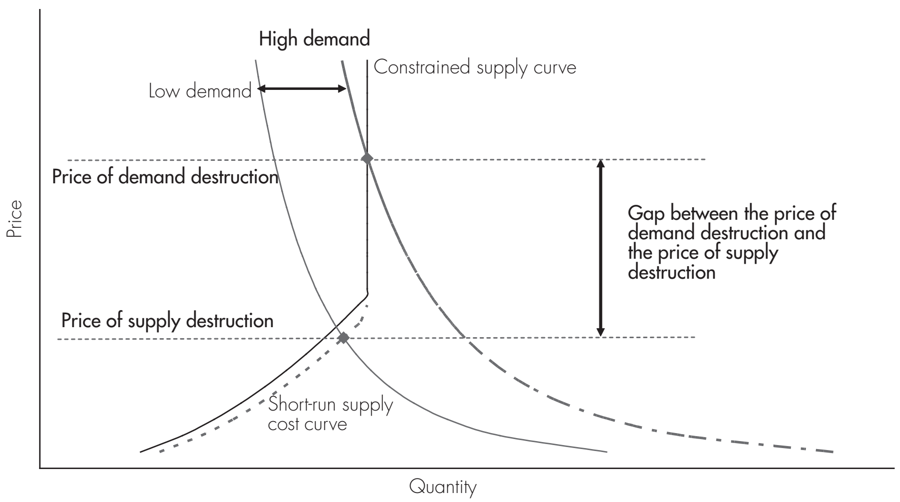


Figure 11 - The price fall, from demand to supply destruction



12. Further, it has a cost to stop and restart production, and it might cause a loss in the total quantity of recoverable resources and an increase in decline rates. As a consequence, a drop below the operational cost might be needed.

3. Where oil prices are heading?

In this context of very volatile oil prices around a surging trend, the aim of this paper is to evaluate how the barrel price should move in the mid- to long-term. For this purpose, we use a supply and demand equilibrium approach; that is, we confront the outlook for oil supply and the outcome of an oil demand model in order first to estimate for the barrel price the equilibrium path that clears the market until 2013, and then to analyse the long-term balance of supply and demand and the potential for a new period of stability.

3.1 The demand model

Our analysis is focused on the road transportation sector. Focusing on a particular sector enables us to make use of a sophisticated model. Looking at total oil demand would imply to rely on a simpler, aggregated modelling approach—unless a global, sectoral and regional energy demand model was to be developed. Road motor fuel demand has shown a very sharp increase in the 2000s, it represents nearly 40 percent of total oil products consumption, this share should keep on increasing (IEA, 2008) and the possibilities of substituting other fuels for petroleum products are currently limited. That's why it is a key factor in the analysis of crude price trends.

Nonetheless, we acknowledge that considering only one sector—even the main one—is obviously a limitation for our approach as this does not allow us to evaluate how much other sectors might tighten or loosen oil markets. In truth, our approach enables us to forecast the price for road motor fuel and not petroleum. Assuming a relatively stable pricing mechanism for petroleum *co-products*—that is relatively stable levels and repartition among finished products of refining costs and margin—introduces a bias in our results as, everything else equal, the upgrading of refining capacity should raise the relative price of road motor fuel, tighter sulphur specifications on bunkers should raise the relative price for middle distillates and stronger requirements regarding refineries' emissions should raise refining costs as a whole in some regions. Running a refining optimization model would be needed to account for all these facts... At some point, simplifications have to be made and assuming no break in the relationship between road motor fuel price and petroleum price should not be too harsh a working hypothesis as refinery yields should not change so much until 2030.

The model used is close to the one developed by Lescaroux and Rech (2008), which relies on a two-term decomposition of per-capita road motor fuel demand: per-capita passenger car ownership rate is expressed as an S-shaped function of real per-capita income and per-vehicle consumption is a usual log-linear function of real per-capita income, real pump prices, car ownership rate and a technological trend. Nonetheless, we do not apply the S-shaped function that they proposed (a log-logistic function) and prefer the one advocated for by Lescaroux (2010); starting with simple assumptions on income distribution and consumers' spending decisions, he justifies a theoretical S-shaped curve (a cumulative log-normal distribution function) describing changes in car ownership as a function of average real per-capita income, income's dispersion and the "cost/utility" ratio of owning a car. On the other hand, The S-shaped function from Lescaroux and Rech (2008) is used to model the number of commercial vehicles per inhabitant, as the rationale for passenger car ownership rate explained by Lescaroux (2010) does not work for commercial vehicles.

To make it simple, we have a three-equation system estimated on a panel of 90 countries from 1960 to 2006 (the period of estimation is shorter for some countries because of missing data). The passenger car ownership rate is expressed as an S-shaped function of average per-capita GDP, whose saturation level is estimated at one car per person in the age of 15 to 80, whose position along the x-axis depends on a "cost/utility" ratio of owning and using a car (positively correlated with average per-capita GDP, but reflecting structural differences between countries) and whose slope depends on income inequality (related to the GINI coefficient)[13] :

$$Car^*_{i,t} = \alpha^\infty \cdot \left[1 - F_U\left(\frac{-\ln(\overline{Y_{i,t}}) + (\gamma \cdot \ln(\overline{Y_{i,t}}) + \beta_i) + 0.5 \cdot \sigma^2_{i,t}}{\sigma_{i,t}}\right)\right] \tag{1}$$

where the subscripts i and t refer to the i^{th} country and the date t respectively, the star denotes long-run optimality, Car is the passenger car ownership rate, α^∞ is the saturation level, $\overline{Y}$ is average *per-capita* GDP, γ and β are the parameters defining the relationship between the cost/utility ratio and average per-capita GDP, σ is the standard-deviation of income distribution and F_U is the cumulative distribution function of the standard normal distribution.

The number of commercial vehicles is an S-shaped function of average per-capita GDP, whose saturation level and slope are common for all countries and whose position along the x-axis differs from one country to another:

$$\ln(Veh^*_{i,t}) = \ln(Veh^\infty) - \ln(1 + \exp(\lambda \cdot \ln(\overline{Y_{i,t}}) + \mu_i)) \tag{2}$$

where the subscripts i and t refer to country i and date t, the star denotes long-run optimality, Veh stands for per-capita commercial vehicle stock, Veh^∞ is the common saturation level, $\overline{Y}$ is average per-capita GDP, λ defines the slope and μ_i is a country-specific parameter.

Per-vehicle consumption is a log-linear function of average per-capita GDP, pump prices, passenger car ownership rate, a technological time trend and a country-specific constant:

$$\ln\left[\left(\frac{Croad_{i,t}}{Car_{i,t} + Veh_{i,t}}\right)^*\right] = \eta^{Car} \cdot \ln(Car_{i,t}) + \eta^P \cdot \ln(P_{i,t}) + \eta^Y \cdot \ln(Y_{i,t}) + \eta^t \cdot \ln(t) + \kappa_i \tag{3}$$

where the subscripts i and t refer to country i and date t, the star denotes long-run optimality, *Croad* and P denote, respectively, per-capita motor fuel consumption and real retail motor fuel price, and the term κ_i is a country-specific effect that corrects for structural differences related notably to regulatory standards or driving behaviors.

13. Basically, assuming that income distribution is log-normal and that consumers choose to buy a car when their income exceeds a cost/utility ratio, the ownership rate is the share of population with an income higher than the income threshold, which is what Equation (1) tells.

For each variable X, a simple partial adjustment mechanism is assumed in the mid-term, of the form:

$$\ln(X_{i,t}) = \ln(X_{i,t-1}) + \delta \cdot \left[\ln(X^*_{i,t}) - \ln(X_{i,t-1})\right] \quad (4)$$

where δ is the adjustment coefficient.

We do not discuss in great details the model as it has already been done elsewhere and the purpose of this paper is not to show econometric models but rather to use them to provide an outlook on future oil prices; more information can be found in the references and is also available upon request.

3.2 Mid-term outlook

Our first concern is about the mid-term outlook for oil prices. To analyse this issue, we simply use the demand model presented above to translate Figure 10 into equation.[14] The principle is simple: with demand expressed as a function of price ($D = f(P)$) and considering a supply forecast, S, we evaluate the market clearing price as $P = f^{-1}(D) = f^{-1}(S)$.

When we run the model with actual past data for input variables in order to evaluate its ability to explain past changes, it performs fairly well in reproducing the price trend observed from 2002 to 2008 (see Appendix 1). This tends to confirm Paul Krugman's reasoning (2008), that speculation "*has no, zero, nada direct effect on the spot price*", at least when looking at annual average prices (see Smith, 2009, for similar arguments in a more academic style and footnote 19 for a more qualified view regarding price changes in 2009). Indeed, the price escalation up to 2006 is quite fully explained. Then, the model overestimates the price level in 2007, surely because it focuses on road transportation and thus it is unable to take heed of the mild US winter at the beginning of the year that slowed down residential demand and pulled crude prices toward $50/b. On the other hand, it underestimates the price level in 2008, maybe because it is not sufficiently detailed to take into account the diesel crunch that occurred until July (see J.P. Morgan, 2009 and Platts, 2009)—notably because of large occasional needs for power generation.

Turning to projections, the explanatory variables for which we need mid-term scenarios are average real per-capita GDP, Gini coefficients and, to some extent, real pump prices.

We use IMF forecasts for macroeconomic assumptions (from the World Economic Outlook Database, April 2009).

Regarding Gini coefficients, there is a huge literature on income inequality. According to Kuznets (1955), it should first rise and later fall as per-capita income increases. Nonetheless, more recent work indicates that this relationship could have weakened or that its capacity to explain variations in income inequality across countries and over time is very limited (Barro,

14. Note that such an approach is designed for mid-term forecasting. As it does not take into account short-term fundamentals (stocks levels notably), it is not supposed to anticipate ups and downs around the mid-term trend.

2000) or that is does not reflect a "natural" evolution but a purely "accidental" evolution (Piketty, 2005). Because of this lack of consensus, we prefer to keep Gini coefficients constant.

Finally, two approaches are used for real pump prices. For a subset of approximately 50 countries[15], we were able to find information on the retail price structure (excise tax, distribution cost and VAT). Thus, the transmission of nominal crude oil price changes to pump prices expressed in real US dollars is performed in four steps. First, changes in nominal wholesale gasoline price in response to changes in nominal crude oil price (both in US$) are simulated according to an econometric relationship. Then, wholesale gasoline price is converted into local currency units. The price structure is applied to get nominal pump prices in local currency units. Finally, these are converted into real US$ prices. For countries where no information was available on the retail price structure, we simply estimate it thanks to an econometric relationship relating nominal pump price to nominal wholesale gasoline price (both in local currency units) and apply the same four-step procedure. We assume no change in the price structure until 2013, except for countries that subsidize pump prices. There is no easy way to deal with this issue and we chose to apply a simple rule of thumb: we evaluate the weight of subsidies on road motor fuel as a percentage of GDP and assume that it will not exceed in the future its past maximal value. Thus, pump prices are kept stable (in nominal local currency units) until the cost of subsidizing gets too high; in such instances, the pump price is raised to maintain the cost (relative to GDP) at or below its past high. Different assumptions on all components of these explanatory variables (macroeconomic variables and notably growth, changes in income distribution or in pump prices taxation/subsidization) may be used for alternative scenarios.

As for the supply side, our assumption on crude oil and other liquids production capacity is from the 2009 Medium-Term Oil Market Report (MTOMR), from IEA. To convert this aggregate capacity into supply for road motor fuel, assumptions have to be made on both OPEC's quota policy and the share of the refinery output devoted to road transportation usages. These parameters are inputs for our price modeling approach. It should be noted that there is a kind of bias in our simulations as we use supply outlook from IEA but our price trajectory may be different. It would be desirable to take into account the relationships between price expectations, investment and future production capacity. Somehow, we correct in part for this bias by adjusting OPEC's spare capacity in response to price signals and by considering in the following an alternative supply case as a sensitivity analysis.

As for OPEC's output, we tried a variety of scenarios and kept as our base case a trajectory for spare capacities that smoothes the price path; accidentally, it is rather close to the one reported in the 2009 MTOMR.

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15. Australia, Austria, Bangladesh, Belgium, Canada, Chile, China, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, South Africa, South Korea, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Turkey, UK and USA.

Turning to the share of the refinery output devoted to road transportation usages, it has been raised from 37.1 percent in year 2006[16] (that is, the last year when detailed sectoral data are available from IEA) to 38.75 percent over the whole projection period for the business-as-usual case. For 2009, this assumption seems consistent with the sharp contraction in oil demand for static usages; notably, it is in line with data available for OECD countries[17] that indicate a 2.4 percentage point combined increase in gasoline and diesel oil yields from 2007 to 2009. From 2010 onward, we assume that no strong rebound effect would occur in oil demand for static usages once economic activity recovers thanks to efficiency gains and substitutions (IEA, 2009). Further, a 70 percent yield in gasoil for Gas-to-Liquids (GtL) and Coal-to-Liquids (CtL) processes has been assumed. Other values for supply and yields in road motor fuel might be used for alternative scenarios.

Assumptions for the baseline case are summarized in Table 1 and the resulting price forecast is reported in Figure 12.[18] What appears is that oil market should soon tighten again[19]. Until 2010, the outlook for supply growth seems barely adequate to cover the increase in demand—at least insofar as mobility is concerned—in a quite depressed economic environment. On the other hand, after 2011, the limited possibilities of expanding production capacity (according to current information) and the rebound in economic activity and road motor fuel consumption should push oil prices to record levels and trigger a new price spike. Of course, emerging countries account for the bulk of the growth in demand. The middle-classes in these parts of the world are earning enough to start buying energy-intensive durable goods, such as automobiles, on a massive scale.

However, there exist many levels which might make an easing conceivable. We tried some alternative scenarios by playing on the level of crude oil supply (since two years or so, IEA's forecasts tend to be considered as conservative by some analysts), on the GDP growth rate, on the share of refinery output devoted to road transportation usages and on vehicle efficiency in developed countries. These alternative cases are based on somehow arbitrary

16. This value was obtained as the ratio of global petroleum product consumption in the road transportation sector to total crude oil supply. Refinery yields in road motor fuel are much higher in OECD countries, close to 34 percent for gasoline and 20 percent for diesel.

17. US DOE: http://www.eia.doe.gov/emeu/international/oilconsumption.html.

18. The simulations were performed in July 2009 after the release of the MTOMR. Like wine—or oil—journal articles are not made in a day and it is almost impossible to publish fresh projections. Yet, the forecast was not out of the cloud for 2009 and the outlook for input variables did not change dramatically—despite an early-2010 upward revision by IMF for GDP growth from 2009 to 2010 and lower figures afterwards although markets are now worrying about a "w-shaped" recovery. Hence, our projections are not fully outdated.

19. We stress again that this kind of simulations provide information on mid-term trends only. Notably, arbitrage opportunities through stock changes are not taken into account. As appears in Figure 12, the price time-spread between 2009 and 1012 is higher than storage costs (close to 0.50-0.85 US$/b/month onshore and close to 1 US$/b/month offshore). Thus, if market participants were anticipating the same trend as us, they should buy crude now to stock it and sell it later. This would increase oil demand and price today but more oil would be available tomorrow, which would lower price expectations. Oil stocks enable to smooth the price path—up to the point where the full storage capacity is reached, a case that was considered in the first months of 2009. Yet, as it did not happen thanks to the opportunity to store offshore, expectations of higher prices and consequent withholding of oil from the market to inventories were central in sustaining prices for the rest of the year (Krugman, 2009).

assumptions and they should only be considered as sensitivity analyses that highlight the influence of the main parameters of the model.

Table 1 - Baseline case assumptions

	2009	2010	2011	2012	2013
World real GDP growth based on market exchange rates (percent)	−2.5	1.1	3.5	4.1	4.1
World real GDP growth valued at purchasing-power-parity (percent)	−1.3	1.9	4.3	4.8	4.9
Total liquids production capacity (Mboe/d)	90.3	92.2	92.7	92.5	93.0
OPEC's spare capacities (Mb/d)	5.2	5.3	4.4	3.1	2.7
Refinery yield in road motor fuel (percent)	38.75	38.75	38.75	38.75	38.75
Road motor fuel supply/demand (Mtoe)	1,688.3	1,718.6	1,748.9	1,776.6	1,804.5

As for the first sensibility analysis, we consider that crude oil supply would be 1 Mb/d higher by 2013[20] (with a linear increase from 2008 to 2013). Regarding the second source of uncertainty, we assume a slower rate of economic recovery, with GDP growth 0.5 percentage point lower for year 2010 and 1 percentage point lower from 2011 to 2013 in each country. Turning to the sectoral allocation of oil resources, we simulate the consequences of a linear increase in the refinery yield in road motor fuel from 38.75 percent in 2009 to 40 percent in 2013.[21] Finally, as regards unit consumptions, we look at the effects of 5.5 percent decline by 2013 in the US and Canada and a 2 percent decline in other countries.[22]

Figure 12 shows the oil price paths that result from these alternative hypotheses. In the 2009 MTOMR, the IEA puts the emphasis on the fact that "*economic growth is arguably the most important variable affecting oil demand*". Indeed, our simulations confirm that

20. Such an increase could result from a higher than anticipated oil production capacity or from a different OPEC's policy.

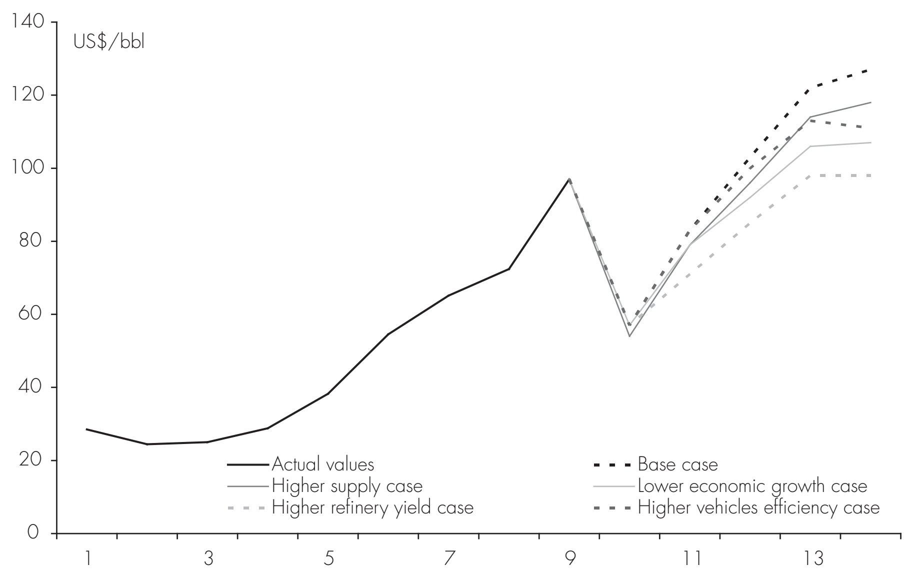
21. As mentioned earlier, there is a slight bias in our approach especially for this case. The upgrading of refining capacity should raise the relative price of road motor fuel and change the correlation between prices for gasoline and diesel and crude oil price. A refining optimization model would be needed to account for this fact. Thus, the Brent price should be slightly lower than our simulation indicates; the price forecast in Figure 13 could be seen as an indication of how much wholesale motor fuel prices have to increase to balance the market.

22. These values were set by considering roughly a 5 percent replacement rate and unit consumption for new vehicles 30 percent lower in the US and Canada and 10 percent lower elsewhere. Of course, they could be challenged. As the aim of this alternative simulation is merely to get an idea of what might happen, we did not refine the hypothesis. More elaborated scenarios will be used when looking at the long-term outlook. Note that the per-vehicle equation already takes into account efficiency gains in response to a price rise; thus, the assumed unit consumption declines are on top of "business-as-usual efficiency gains".

a slower rate of GDP growth would lead to lower oil prices. Nonetheless, at least as much important are the effects of optimization of oil products consumption: an adjustment of refineries output towards higher yields for products used in non-static usages (and especially road transportation) would result in a much looser market. Further, Governments in importing countries will not try to depress economic growth just to make the barrel price cheaper. From the standpoint of energy policy makers, the options are to stimulate supply growth, to promote efficiency gains or to prompt substitutions in order to make more oil available for oil-dependent sectors.

What appears from our simulations is that the last one seems to be the easier solution in the mid-term. Over that time horizon, the impact on oil prices should be stronger than the one resulting from other, more difficult or costlier strategies: on one hand, Governments in importing countries have little power to raise oil output considering geopolitical constraints; on the other hand, allocating public funds to hasten the retirement of the existing vehicle fleet and its replacement with more efficient vehicles might be a part of a stimulus package, but the cost for such measures is usually high. On the contrary, it should be highly efficient to implement relatively simple and low-cost policies aimed at accelerating substitutions away from oil for heating, power generation and industrial (non-petrochemical) activities. At all events, we still observe a tightening of oil markets even if the mid-term trend is sometimes much less bullish than in the base case. Indeed, in a five-year time frame, the opportunities to deviate oil prices from their business-as-usual trajectory are rather limited.

Figure 12 - Brent price forecasts



3.3 Long-term outlook

Turning to the long-term outlook, we prefer to make use of a different approach. Indeed, long-term demand simulations relying on price elasticities tend to perform poorly and, mostly, it would not be realistic to try to anticipate retail price structures over two decades. It seems more sensible to neutralize the price effect in the demand model and consider directly assumptions on the impact of energy policies on vehicles' efficiency. Yet, the previous analysis concludes that such measures should not be sufficient to prevent a supply shortfall in the coming years. Thus, we use the demand trajectory from the base case of our mid-term simulations up to 2013 and then project the trend path by feeding the model with exogenous efficiency assumptions from 2015 to 2030 (the short- to mid-term and mid- to long-term simulations are linked together by linearly interpolating the value in 2015).

On the one hand, we do not hypothesize any significant change in vehicles mileage. On the other hand, we use projected fuel economy standards for new vehicles from ICCT (2009). For seven countries or region (Australia, Canada, China, Europe, Japan, South Korea and US), it provides a trajectory for miles per gallon (mpg) over different time horizons going up to 2020. Depending on the country considered, different tools and public policies should be implemented to reach such standards (ICCT, 2009): for example, they still are voluntary in Australia whereas they are or will be mandatory in other places; highly progressive taxes are levied on the gross vehicle weight to enforce compliance in Japan, China has raised in 2006 the excise tax rate on large-engine vehicles while lowering it on small-engine vehicles, tax credits are considered for highly fuel-efficient vehicles in the US and some European countries and, of course, retail price structures could be adjusted (notably by incorporating a tax on greenhouse gas emissions). These standards are prolonged up to 2030 assuming a progressive slow down in efficiency gains. For other countries, a convergence towards developed countries' standards is considered. Finally, simple assumptions on replacement rates enable us to project average efficiency measures for the whole fleet (we classify countries according to their income level and assign to each group a given replacement rate, ranging from 6.5 percent for high-income countries to 4 percent for low-income countries; again, more information is available upon request).

Overall, our efficiency scenario is voluntary but still reasonable. It relies mainly on existing technologies (downsizing and hybridization) but assumes that these will spread quickly into vehicles' fleets and hence that drivers' tastes will change dramatically in some parts of the world. As for Plug-in Hybrid Electric Vehicles (PHEV) and fully electric vehicles, we do not anticipate a sharp increase in sales up to 2030 as—in the absence of technological breakthroughs—they should struggle to become attractive on a pure cost-benefit basis over that horizon (DOE/EIA, 2009); nonetheless, we will come back later on the consequences of a potentially larger post-2020 PHEVs' penetration. Roughly, our scenario stands between IEA's reference and 450 scenarios (IEA, 2009, p. 239). We acknowledge that the whole set of assumptions is really rough and simple for most countries. Nonetheless, it still makes sense for long-term simulations as it should provide some idea of future trends, especially in the main consuming countries where official efficiency standards for new vehicles are used on a large part of the projection period.

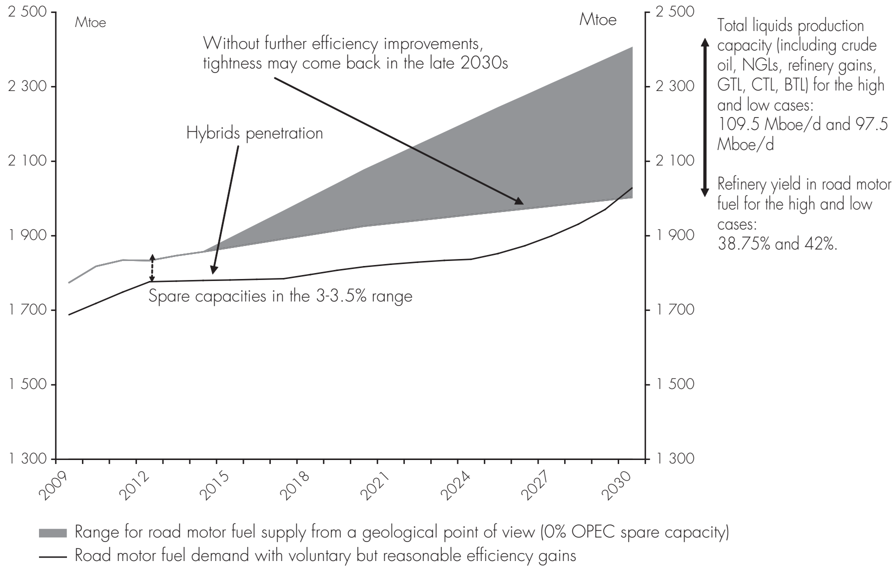
We introduce this scenario in the per-vehicle consumption equation of our demand model. The long-term simulations performed suggest that road motor fuel demand may roughly flatten from the mid 2010s to the mid 2020s thanks to gains in unit consumption due to hybridization and downsizing of the fleet (see Figure 13). Of course, this means massive investment from consuming countries, for Governments and mostly for individuals. But a strong short-term rebound in the oil price would make a great incentive to engage the process.

As for supply, the long-term outlook from IEA (2008) and the main other institutions imply that total liquids production capacity could stand between 105 and 110 Mb/d by 2030. The realism of such scenarios raises many critics from the so-called "pessimists", who point out that this implies the development of something like 50 Mb/d of new capacity, accounting for the depletion of currently producing fields. According to press statements by CEOs of major oil companies (Total and ConocoPhillips for example; see Deutsche Bank, 2008), it may be more reasonable to expect a total production capacity level between 95 and 100 Mb/d. Thus, we consider a band for liquids supply ranging from 97.5 to 109.5 Mb/d. As mentioned previously, a rise in the refinery yield in road motor fuel might have a very strong impact on the supply and demand balance; thus, we keep it stable at 37.75 percent in the "pessimistic" case but raise it to 42 percent by 2030 in the "optimistic" case (as a benchmark, the IEA anticipated a rise in the global share of transport in primary oil demand from 52 percent to 57 percent between 2006 and 2030 in the 2008 edition of the World Energy Outlook).

The confrontation of supply and demand outlooks reveals that, if all required investment—both on the supply- and the demand-sides—was to be done on time, oil markets could get into control again, even in a case of low supply growth (see Figure 13). Then, a "great bargain" would take place again, as in 1986. OPEC would be able to pick up a price below the substitute's cost and above its production cost. Yet, OPEC would have to consider the price band for other countries too, whose ceiling is the level where economy is hurt and whose floor is the minimal price level for not putting—too much—at risk investments already made in high-cost oil resources and expensive energy conservation measures.

According to the most recent estimates, the long-run marginal cost of supply for conventional resources (including a 15 percent return that allows to maintain at a corporate level the R/P ratio) stands close to 60-70 US$/bbl. Breakeven oil prices on new projects are evaluated (Deutsche Bank, 2009a) at $60/b in Brazil and Nigeria deep water (OPEC member), at $62/b in the US Gulf of Mexico and at $68/b in Angola (OPEC member). New projects for Canadian non-conventional resources are more expensive, in a 70-80 US$/b band, and they could become still more expensive if a CO_2 tax was to be imposed. As for substitutes, the breakeven price for XtL processes (Biomass-to-Liquids, Gas-to-Liquids and Coal-to-Liquids, the last two being also exposed to a risk of environmental taxation) is close to $110/b while the next generation of plug-in hybrid and electric vehicles should be economic at $90/b and $125/b (Deutsche Bank, 2009b).

Figure 13 - Outlook for road motor fuel supply and demand balance



However, there is a cyclical component in most drivers of the cost inflation observed since 2003. For instance, raw materials and oil services experienced recently a dramatic escalation because the unanticipated acceleration in demand caused shortages in resources to appear—both material and human. At another level, upstream taxation has been adjusted upward in many places, including some OECD countries (UK, Canada), reflecting the change in the balance of power between producing countries and companies. These factors—all of them being at work at the beginning of the 1970s too—have pushed capital and operational costs higher and they may continue in the short-term, but they should correct downward in part over the mid- to long-term if we manage to restore spare capacities. Yet, the dynamic should be different than 35 years ago. At the time of the "first" oil shock, the sudden price rise has been perceived at first as a structural break in oil markets, and investment by oil producing and oil services companies has responded quickly; to the contrary, many analysts—if not the consensus—have seen for a rather long time the gradual price increase since 2002 as a temporary phenomenon and they failed to understand that a new long-term shift was occurring, thus preventing investment to react in time. On the other hand, the mid-1980s price collapse has been abrupt too, as OPEC desperately persisted in defending too high a price level by contracting output from 1982 to 1986; hopefully, OPEC and some other producing countries have learnt from their mistakes and they will not again swim against the current but accept a gradual decline in oil prices—to be offset by rising export levels—if the balance of power turns to their disadvantage.

Thus, the oil price could smoothly stabilize somewhere in the 75-110 US$/b range by the end of the 2010s; afterwards, OPEC would be able to keep it for some time by adjusting its production quotas, like in the 1990s.[23] Again, excess capacities would induce companies to try to cut costs; deflation in raw materials' prices and in the oil services industry, contract renegotiations and/or learning in now non-conventional production techniques would "race" once more against depletion—and should win until the next period of turbulence, thus preventing nominal production costs to increase. Of course, it is impossible to forecast the impact of future unknown productivity gains in frontier resources, and thus to what extent they will compensate for the cost-increasing effects of depletion; but symmetrically, no one can guarantee that they will not be sufficient to prevent a cost escalation and that prices are doomed to rise steadily just because more complex resources will be required. What we know for sure is that dominant players did manage to keep nominal prices flat for long periods in the past (Figures 1, 2 and 3), following periods of fears about future supply just as strong as today's concerns.

Yet the period of control might well not last for long. Efficiency gains may offset the structural increase of the vehicle fleet for some years, but global road motor fuel demand should turn up again in the late 2020s (Figure 13). If crude oil supply and refinery yield were to be on the "pessimistic" side of our scenarios, tightness would resume without another technological advance on the demand-side. The main candidates for now are long-range full electric cars and mainly PHEVs. If sustained R&D efforts were to allow automakers to make future advances in battery technology by 2020, then large-scale sales could materialize and, depending on the rate of diffusion into the fleet, road motor fuel demand could keep flat. It would seem reasonable to expect that the higher OPEC sets the equilibrium price, the longer the next stability period: on the one hand, a costlier barrel would make more petroleum resources economic (raising 1P reserves) and it would limit global growth in petroleum consumption (slowing down production); on the other hand, too low a price level may slow down R&D efforts in technologies required to avoid a post-2025 supply shortfall.

4. Conclusion

One of the main features of the oil market is its natural tendency to experience an alternation of periods of turbulence and periods of stability. This fact has been observed a very long time ago and results from long investment cycles that are responsible for the succession of over- and under-capacity periods, as well as the market's natural tendency to turn into some form of control during periods of excess capacity.

After fifteen years or so of stability, a new petroleum crisis has begun in the mid-2000s. Again, insufficient investment has led to a situation of immediate supply shortfall and rising fears about future oil availability. So to speak, the economic recession has given us some rest, with prices falling from $150/b to $40/b at the turn of 2008 and 2009 while the

23. Sadly, oil price expectations are self-destructive: oil producers and consumers have to believe that something like the DOE's or IEA's scenario will happen to invest enough, and our prediction will not materialize if too many players believe in it and do not invest.

market was switching from demand to supply destruction. Nonetheless, our simulations indicate that the petroleum crisis is not yet over. A resumption of the price rise to new highs—above the three-digit threshold—is very likely in the coming years, unless the crisis is more severe than anticipated. Substitutions away from oil in heating, power generation and industrial activities could play a great part in making more oil available for oil-dependent sectors and ease the tension in oil markets. Nonetheless, within a 5-year time frame, it should be difficult to avoid a new "shock" regarding the amount of investment needed for managing the gap and preparing a transition away from oil.

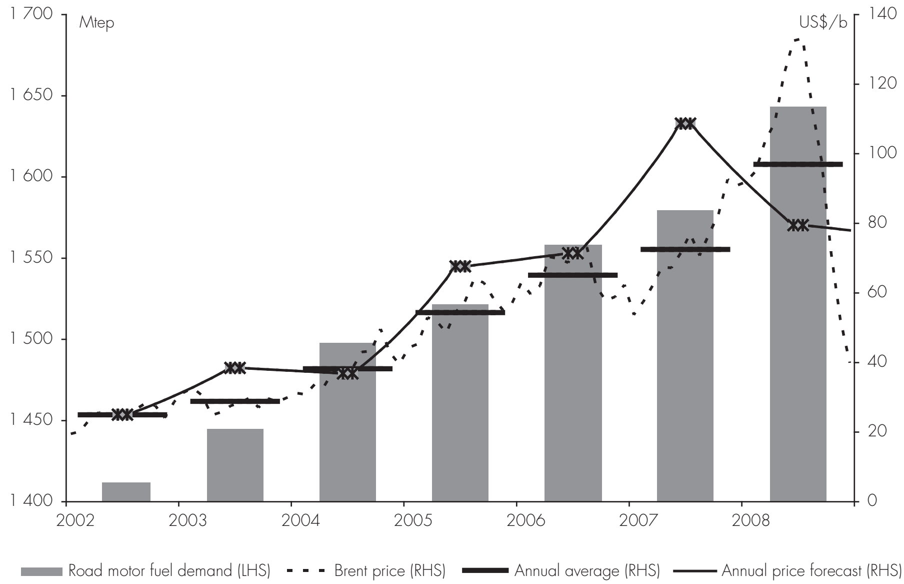
On the other hand, the long-term outlook is not so bullish. Accounting for voluntary but reasonable efficiency gains on the demand-side, petroleum demand may flatten from the late 2010s to the late 2020s. Even in a "pessimistic" case for supply growth, we should be able to build up again spare capacities and raise the R/P ratio. Thus, the market could enter a new stability period with a price somewhere between \$75/b (that is, approximately the marginal production cost) and \$110/b (that is, approximately the price level that would strongly encourage research on electric vehicles and PHEVs, hence threatening oil demand). If this was to happen, the abundance of oil resources relative to demand would put downward pressure on prices. Companies would be strongly induced to cut costs and productivity gains could well take the lead again in their race against depletion. Of course, we cannot forecast the effects of future technological and organizational innovations. However, the argument that real prices will rise steadily because more and more expensive resources will have to be produced is weak and does not take into account the fact that learning by doing may significantly lower production costs for now "frontier" resources, just like it did in the 1990s for North Sea oil or Canadian sands. For what it is worth, history suggests that prices could well stabilize in nominal terms.

F. L.[24]

24. The author is indebted to P. Alba, N. Alazard, O. Appert, F. Birol, J. Laherrère, D. Martin, M. Schenckery, A. Sieminski and J.L. Vermeulen for valuable comments on an earlier draft. He also wishes to thank—honestly—the editor and two anonymous referees for helpful critics and suggestions, as well as O. Rech for priceless discussions and advices.
The views expressed are the author's and not necessarily those of IFP, GDF SUEZ or anyone who helped improving the analysis.

Appendix 1

Figure A1.1 - Dynamic Brent price forecast vs. actual values



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