Bachelor's Thesis

Hotelling's model in practice

Is the current rate of oil extraction efficient?

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Chapter 1 - Introduction

1.1 Introduction

In his State of the Union speech on Februari 1st 2006, President Bush addressed the issue of the American economy's heavy reliance on oil, stating that this "addiction to oil" should be broken by means of the introduction of new technologies. The president announced a 22% increase in funding for clean energy research, focusing on renewable natural resources and nuclear energy.

Fears of depletion of the world's oil reserves and calls for the adoption of alternative (sustainable) sources of energy are not exactly a phenomenon of recent times. In fact the first concerns were raised as early as the start of the 20th century. The major difference between then and present day, however, is that at that time the rate at which new oil fields were being discovered was relatively fast. Whereas today, the world's largest conventional oil fields are expected to be exhausted within foreseeable time and the rate at which new oil fields are discovered is much slower. The majority of studies investigating the world oil production forecast that it will peak somewhere between 2010 and 2050 and decline afterwards. It is no wonder that calls for switching to durable energy are getting stronger.

1.2 Aim of the research

According to resource theory, oil will continue to be used until its price reaches a certain choke point. After the choke price is reached, other energy sources will be substituted for oil, examples being solar or wind energy. Furthermore, theory states that the efficient path of the oil price will be such that depletion of the oil stock will occur exactly at this choke price (Hotelling; 1931). Therefore in theory we should not need to worry about extraction paths of oil for efficiency reasons.

But does such a mechanism also exist in practice? Should we be worried about the current extraction rate of oil for efficiency reasons? This is what I will try to answer in this paper. My central research question will be:

Can the current extraction rate of oil be considered efficient?

1.3 Structure of the thesis

Chapter 2 starts with an explanation of how resource theory arrives at the efficient path of oil extraction. The mechanisms that I will describe are mainly based on Hotelling's non-renewable resource theory. Here I will start out with the basic assumptions of perfect competition and a fixed, finite stock of oil. The discussion of the theory is primarily based on the explanations by Perman et al. (2003)

In chapter 3 I will look at the practice and see if a similar price path predicted by the theory is visible. It turns out that such a path is hardly ever observed in the real world. Several assumptions that lead to the Hotelling optimal price path appear to be violated in practice. I will briefly discuss a few of these imperfections, namely the influence of market power (exerted by the OPEC oil cartel), unanticipated discoveries of new oil fields, (unanticipated) technical change and imperfect expectations (futures markets)

In chapter 4 I will look at one of these imperfections, namely the imperfect functioning of the futures market, more in depth and see to which degree the price path we see in practice can be explained by the real working of this market. A well functioning futures market should allow contracts to made that can specify any future delivery date until the point in time where choke price is reached and a backstop technology is adopted. Also investors' expected prices should match the actual future prices. Therefore this section will mainly concentrate on whether current futures contracts can predict future prices.

Finally, chapter 5 will conclude by comparing the behavior of actual oil prices with the behavior predicted by theory and summarizing whether the actual price behavior can be called efficient.

Chapter 2 - Theory

2.1 Introduction

Non-renewable resources can be classified into two groups: Fossil fuels (such as oil, natural gas and coal deposits) and minerals (such as iron and copper.) By definition these resources are formed by geological processes that take place over millions of years. Since the time scale of this process is far too great to be relevant for humans, it makes sense to think of the stocks of these resources as fixed. This implies that they will eventually be depleted if continued to be used in the production process.
The model I will be using to explain the oil price path is based on a rule for dynamic efficiency which is often used in non-renewable resource economics, the Hotelling rule. It was first developed in 1931 by Harold Hotelling.

Before explaining the model, I will start by making several (unrealistic) assumptions that will help simplify the analysis:

- First, I will assume that the oil extraction market is perfectly competitive, implying that there are an infinite number of resource owners that have no influence on the market price of oil. Furthermore, the social discount rate (also the interest rate), which I will denote by *r*, will be equal to the private discount rate faced by all firms in the market.
- Second, the total stock of oil will be assumed to be fixed. This means I will abstract from any unexpected discoveries of new oil reserves.
- Third, I will assume that resource owners and society as a whole derive utility from extraction of oil directly and not from the consumption of oil or from goods that were produced by using oil as an input.
- Fourth, I will assume that there is no (unexpected) technological change that could suddenly make alternative sources of energy more attractive for exploitation or that would lead to a more efficient use of oil in the production process.
- Lastly, I will abstract from any external effects that extraction or consumption of oil might have on the environment.

2.2 The Hotelling Rule

The core of the model is the Hotelling rule, which requires the price of oil to grow over time at the discount rate. Denoting the oil price as *P* and the discount rate (or interest rate) as *r*, this condition can be stated as:

$\dot{P} = rP$, or equivalently: $P_t = P_0 e^r$

The reason behind this optimality condition is that natural resources can essentially be thought of as capital goods. This means that the owner can make capital gains on the resources as long as they are unexploited; that is by preserving them. If the price of the resource grows at the interest rate on other (capital) assets, then the present value of extracting any amount of the resource at any point in time in the future will be equal to the value of extracting the same amount of the resource today. Hence the owner will be indifferent as to whether to exploit the resource or leave it in the ground. This is a necessary condition for dynamic optimization in order for welfare to be maximized over all time periods.

In a diagram, the Hotelling Rule can be shown as:

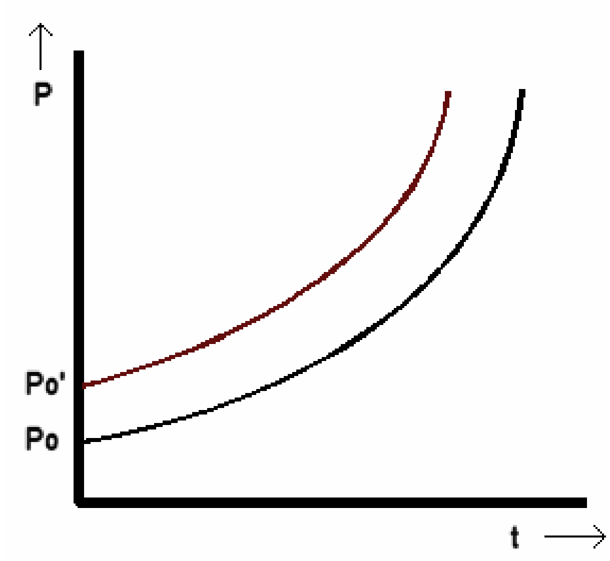

Figure 2.1, Hotelling rule

Where the price of oil *P* is on the vertical axis and time *t* is on the horizontal axis.
Given the discount rate, the actual price path still depends on the initial price *Po*, as can be seen from the diagram.
Both paths in fact satisfy the Hotelling rule. However, only one of these can be optimal given demand and the initial stock of oil.

Determining the optimal price path is what I will do next.

2.3 Optimal resource use

Since oil is a non-renewable resource, by definition it will be depleted at some point in time. The depletion time *T*, as well as the initial price *Po*, can be determined by including demand and the initial stock of oil into the analysis:

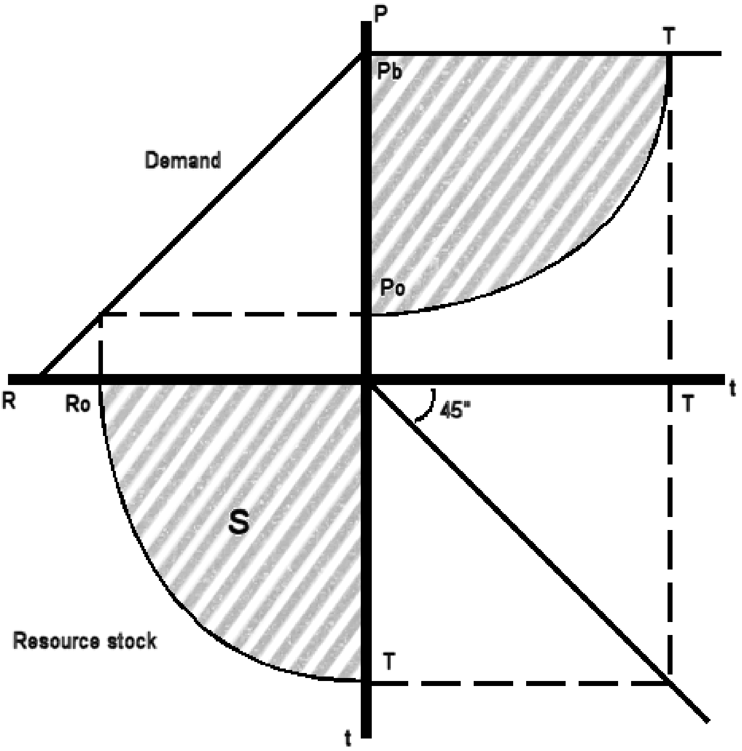

Figure 2.2, Hotelling Model

The lower left quadrant of the Figure 2.2 (reproduced from an original graph by Perman et al.) shows extraction of oil over time. At every point in time *t*, the stock of oil will be reduced by R_t until it is completely depleted at time *T*. Hence the total stock of oil *S* is the total area under the extraction curve and can thus be stated as: $S_0 = \int_0^T R_t dt$

The upper left quadrant shows the total demand for oil, which is equal to extraction *R*, for every price *P*.

The upper right quadrant again shows the price path of oil as predicted by the Hotelling rule. It now also shows the time of depletion *T*, which occurs at the choke price *Pb*. This price represents the point at which oil is completely substituted by other sources of energy, which could either be unconventional deposits of oil (such as oil from tar sands) that were until this time economically unrecoverable, other non-renewable resources such as natural gas, or sustainable resources such as solar or wind energy. These alternative substitutes are known as possible ‘backstop technologies’. As can be seen from the figure, demand for conventional oil also falls to zero at the choke price.

The price path depicted in Figure 2.2 is the optimal path as it satisfies two conditions:

- Price grows at the discount rate (Hotelling Rule)
- Depletion of the oil stock exactly coincides with demand falling to zero and substitution of alternative sources of energy (i.e. *Po* is optimally chosen)

The first condition of optimality was already explained earlier in the analysis. The second condition can be verified by looking at what would happen if the initial price would be different from *Po*:

- If the initial price was higher than *Po*, demand (and therefore extraction) *R* would be lower than optimal at every point in time. Furthermore, the price of oil would reach the choke price earlier then *T*, meaning that not all of the oil stock will be depleted. Substitution will still take place, thereby leaving some oil reserves wastefully in ground.
- If the initial price was lower than *Po*, exactly the opposite holds. Demand would be higher than optimal at each point in time and the oil reserves will be depleted too quickly, even before the oil price reaches the choke price. Since the price of energy substitutes will have remained the same, a jump in price is required to switch to these alternatives.

Up until now I have assumed zero extraction costs. However the conclusion of the model still holds if these are included. The Hotelling rule in case of constant marginal extraction costs would be:

$\dot{p} = rp$, or equivalently: $p_t = p_0 e^r$, where $p = P - c$

That is, in this case the net price (or royalty) *p* rather than the gross price *P* grows at the discount rate.

2.4 Conclusion

To satisfy the dynamic efficiency criterion, the Hotelling model predicts an upward sloping price path over time. In the next section I will look at whether the price of oil exhibits this behavior in the real world and if not, what possible causes there are of this divergence from the theory.

Chapter 3 - Oil prices in practice

3.1 Introduction

According to the Hotelling rule, if looking at historical oil prices, one should expect to see an upward trend. Prices (or royalties) would be expected to grow exponentially over time. In practice, however, they do not, as can be seen from the following figure that shows the development of crude oil prices from 1860 to 1999, adjusted for 1999 US dollars[1] and from 1990 to 2005, adjusted for 2005 US dollars[2]:

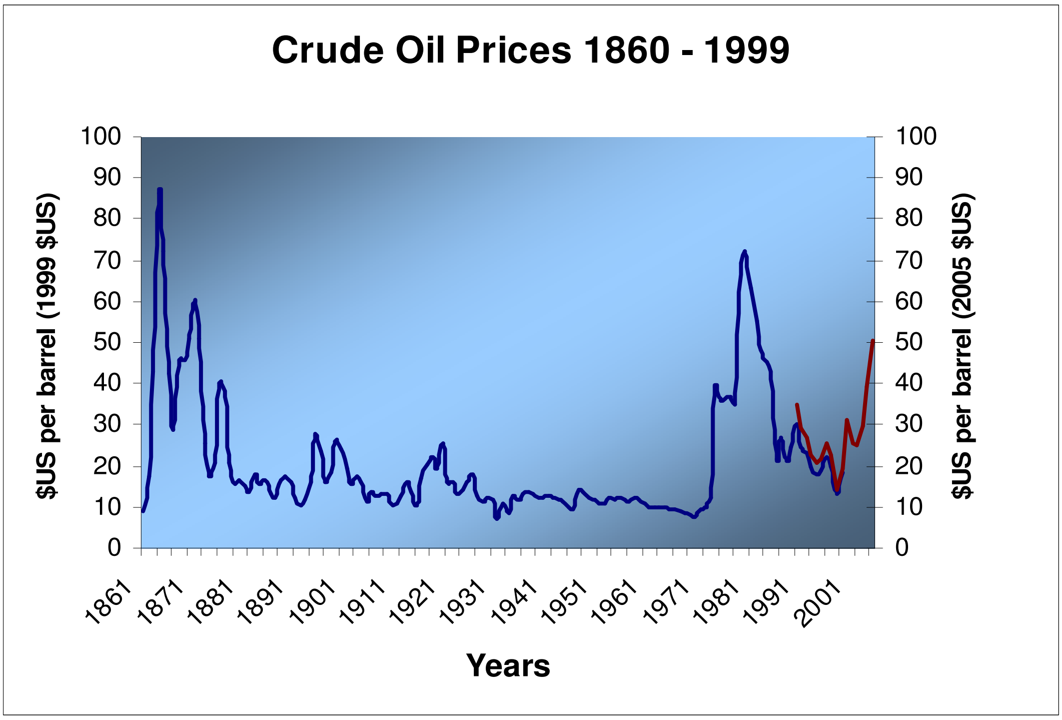

Figure 3.1, Actual oil price behavior, US Energy Information Administration; Illinois Oil & Gas Association

True oil prices then seem to be much more volatile then the Hotelling rule would lead us to believe. The reason for this is that in the real world the interest rate and initial prices are not the only factors that influence price behavior over time. Indeed, several necessary conditions for the model I explained in chapter two to apply are not valid in reality. In this chapter I will look at several of these key imperfections and explain what would happen to the oil price path if they are present.

The imperfections I will look at (following the argument of Perman et al.) are:

- Market power,
- Unexpected discoveries,
- Unexpected technological change, and
- Imperfect institutions (futures and forward markets).

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[1] Source: US Energy Information Administration, http://www.eia.doe.gov/

[2] Source: Illinois Oil & Gas Association, http://www.ioga.com/

3.2 The influence of market power

As stated in chapter two, if the Hotelling rule holds, welfare will be maximized over all periods. However, the rule only holds if resource markets are perfectly competitive. This is clearly not the case for the oil market in practice, as it is instead characterized by a few large producers, most of which are concentrated in the Middle-East. This concentration has in fact facilitated the formation of an oil cartel, the OPEC, which could use its dominant position to influence world oil prices. Still, several (smaller) oil producers (called "the fringe" in the literature) remain outside of the cartel. These fringe producers are usually assumed to act as price takers. "Cartel-versus-fringe" models that describe the behavior of resource cartels, including the strategic interaction between these cartels and the fringe, as first introduced by Salant (1976), have been extensively investigated in the literature. Some of these models assume the cartel to follow the same price taking behavior as the fringe producers, while others attribute more or less market power to the cartel by assuming it to act as a Stackelberg market leader.

For the purpose of this paper I will assume that the OPEC has at least some market power, enabling it to influence world prices. If this is the case, then the Hotelling rule will no longer be valid. Moving together as a dominant firm, the cartel will restrict output by conserving more of the oil than a competitive producer would. This causes the price of oil P_0 to go up. In addition, the cartel's behavior will cause prices to increase at a slower rate:

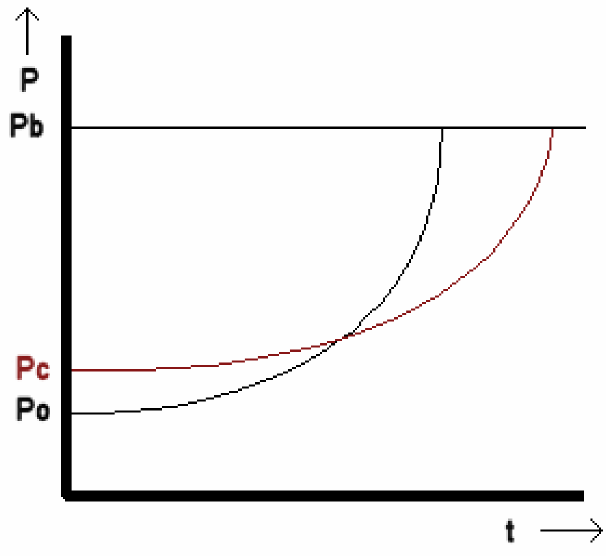

Figure 3.2, The influence of market power on oil prices

This "conservationist" behavior, although it does not nearly reflect all the strategic interactions involved in real markets, already shows that the Hotelling rule does not hold in the presence of market power.

3.3 Unexpected discoveries

As explained in chapter two, the optimal price P_0 should be such that depletion of the total stock of oil occurs exactly at the point where adoption of a backstop technology becomes economically viable. The initial price thus dependents on the initial stock of oil, which was assumed to be given and fixed in the model of chapter two. In reality, the stock is not fixed, but may grow over time as new oil fields are discovered and exploited. Such discoveries also influence the price of oil.

Since the stock of oil can be stated as $S_0 = \int_0^T R_t dt$, it follows that more extraction must take place in order for the stock to be depleted. Given the demand curve, more extraction then requires an immediate drop in the price.

In case of a single discovery, the resulting price path is therefore everywhere below the original path and depletion will occur at a point in time later than *T*.

In case of frequent discoveries, the actual price path may look like this:

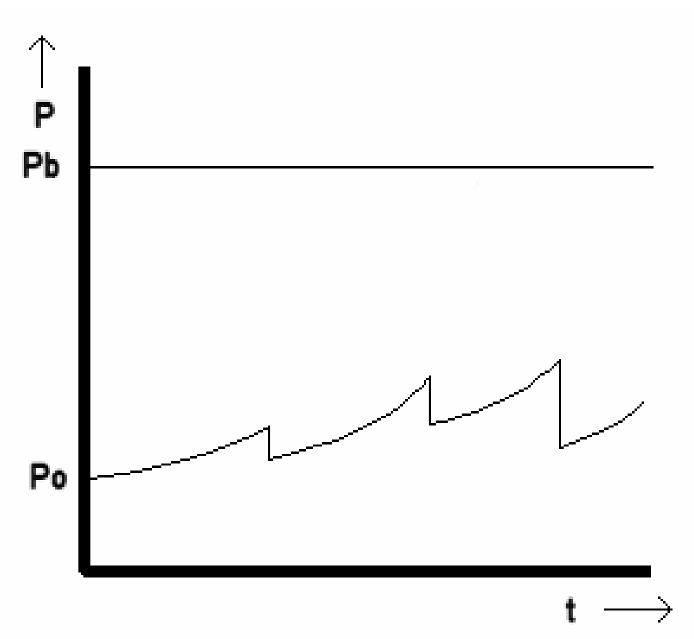

Figure 3.2, Hotelling rule with frequent discoveries

Figure 3.2 shows that if discoveries are frequent enough, it may lead oil prices to be constant or even decreasing over time. This might explain some of the actual behavior of oil prices shown in Figure 3.1 However, even though the prediction of the model is inconsistent with reality, it does not mean that the Hotelling rule itself can immediately be refuted if frequent discoveries take place. Between discoveries, prices still grow exponentially at the interest rate.

3.4 Unexpected technological change

Another element influencing the price of oil that was assumed away in the model of chapter two is the effect of technological change. This effect can actually work in two ways, depending on in what area technological progress takes place.

One effect could be a decrease in the cost of implementing the backstop technology. Given the original price path, this would mean that switching to alternative energy sources would become economically viable at a point in time earlier than *T*. Some of the oil would therefore be wastefully left in the ground. In order to avoid this, extraction at each point in time should be increased through a drop in the initial price of oil.

A second effect could be a fall in the extraction cost of oil itself. This causes an increase in the resource royalty or net price $p = P - c$. In the presence of extraction cost, it is this net price that grows at the discount rate. Since it will now be higher initially, the gross price would grow at a faster rate than before, causing the price of the backstop technology to be reached sooner than *T*. Since this is again inefficient, a fall in the initial gross price is required. The result is a new price path that starts out lower than the original one, but grows at a faster rate:

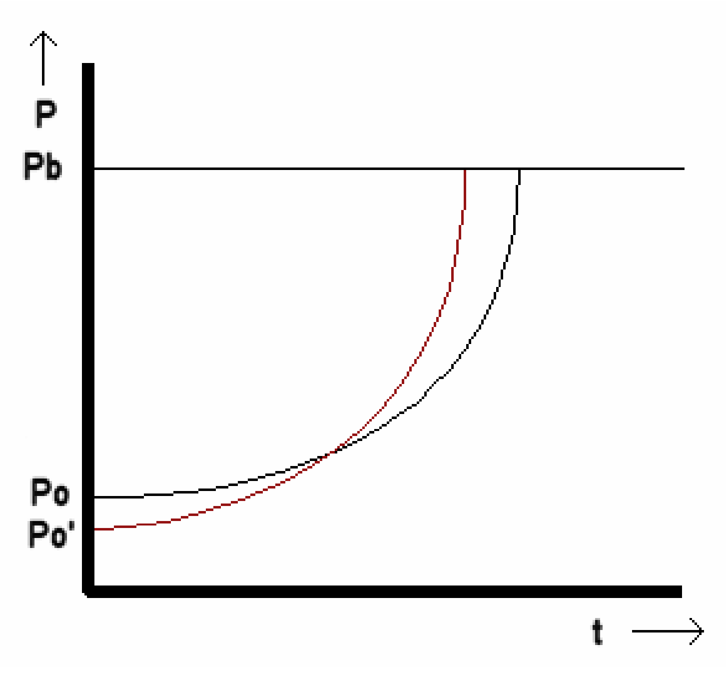

Figure 3.3, The effect of a fall in extraction costs

Especially this latter effect of technological change could be an explanation for some of the actual behavior of oil prices shown in Figure 3.1. As it turns out, a fall in extraction costs is followed by an immediate drop in the gross price of oil and a subsequent increase in the rate of price growth. This behavior can actually be seen in some parts of Figure 3.1.

3.5 Imperfect futures markets

The Hotelling rule further assumes that resource prices must grow at the discount rate in order to satisfy the dynamic efficiency criterion. Of course, in the real world just the goal of dynamic efficiency is not enough to direct the development of oil prices. Whether actual oil prices grow at the discount rate depends for a large part on whether investors and oil producers *expect* it to do so. And even if they do believe that oil prices follow the Hotelling path over the long run, then still any unexpected event (for example an announcement that current reserves have been over- or underestimated) will cause them to change their expectations and behavior accordingly. The same holds for other, non-economic world events such as the Gulf and Iraq wars, which may have had a large impact on investors' expectations (as Figure 3.4. shows).

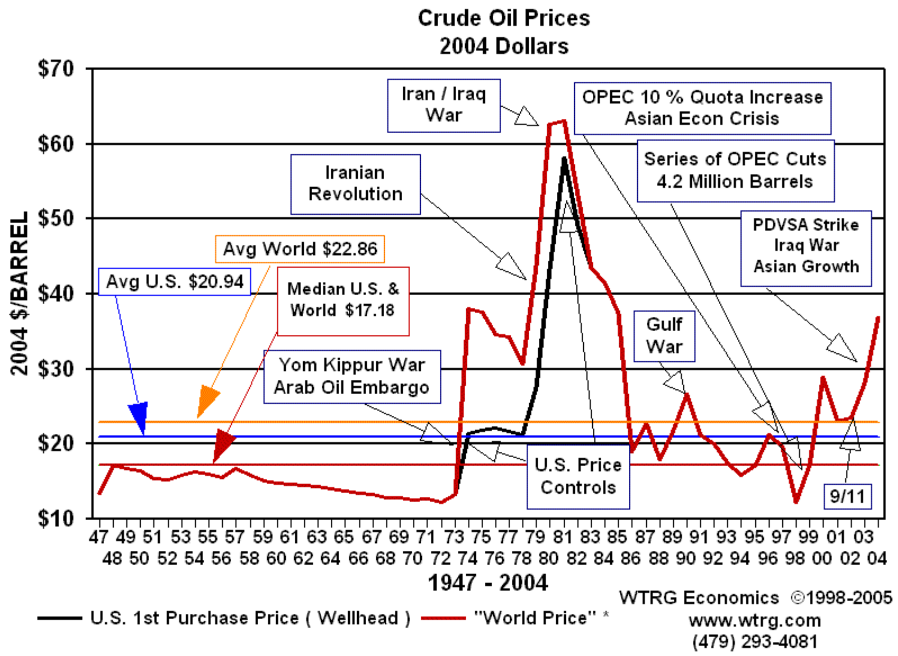

Figure 3.4 World events possibly leading to oil price shocks, WTRG Economics

This changing of market expectations may be able to explain some of the (sudden) peaks and drops in the price of oil observed in the data of Figure 3.1. Volatility on the spot market could thus be a major determinant of actual oil prices.

However, even if spot prices are highly volatile, the existence of efficient futures markets may still cause prices to rise at the discount rate by allowing investors to hedge risk. If investors initially expect that prices do develop according to the Hotelling rule, then futures markets will allow them to make transactions at those expect future oil prices and thereby transfer the risk to other players on the market that are more capable of bearing this risk (such as large institutional investors)

3.6 Other reasons why prices diverge from Hotelling's expectations

Aside from the imperfections described above, there are other reasons why the actual extraction path may be different from the one derived in Hotelling's model.

First of all, some imperfections may interact with one another and others may not hold in the long run. The existence of a cartel such as OPEC on resource markets for example influences the behavior of other actors. On the demand side, when faced with the cartel's higher prices, some industries that use oil as an input in their production process may find it profitable to invest in the development of alternative energy sources. A cartel's price setting behavior may thus spur technological progress, possibly leading to an earlier adoption of a backstop technology.
On the supply side, oil exporting countries outside the cartel, such as Russia, may take advantage of the higher world market price due to the cartel's supply restriction by increasing extraction of their domestic oil reserves and exporting more. In addition, members of the OPEC itself may be tempted to secretly supply more than the agreed volume if the profits of doing so are higher than the cost of getting caught. The OPEC cartel as a whole may as well deviate from its agreement if the one-time profit of producing more is high enough.
Due to these demand and supply side effects, the cartel may not be stable over the long run.

Furthermore, in order for extraction to take place, oil producers must first invest in the necessary capital goods, such as pumping stations or drill platforms. If capacity costs are positive, then efficient extraction demands that the capacity should be just equal to the extracted amount, so that none of it is wastefully left unused. An increase in demand for oil should therefore first require the producer to invest in new capacity, which should then be immediately available in order to meet the increased demand. In the real world, however, installing new capacity may be expensive and time consuming. An increase in demand in this case will therefore not be immediately met as the producer faces a capacity constraint. If all producers face this constraint, then this will lead to a temporary price increase.

3.7 Empirical tests of the Hotelling rule

The Hotelling rule has been extensively tested in the resource economics literature. In this section I will discuss a few of these studies.
Barnett and Morse (1963) found that non-renewable resource prices display an overall horizontal trend over the period between 1870 and 1957. They conclude that the Hotelling rule does not hold for the majority of natural resources.
Slade (1982) found in a first study that the price developments of a large number of natural resources show a U-shaped path rather than a convex path. In a later paper (1991) she shows however that

prices after the sampled period turned out to be very volatile, which implies that there is no sustainable trend in resource prices.
Pesaran (1990) investigates the formation of price expectations. He finds that adaptive expectations (i.e. expectations based on past price developments) are better supported than rational expectations implied in Hotelling's model.
Teece et al. (1993) investigate different types of resource cartels and their impact on resource markets. For the oil market they discuss three different views of the market's cartelization. The first view is that OPEC acts as a cartel with Saudi-Arabia as its leader. The second view is that the oil price increase in the 1970s was not due to the OPEC cartel but due to market mechanisms. The third view is that OPEC acts as an instrument to the member countries' governments to satisfy their budgetary needs. Griffin (1995) finds support for the first view.

3.8 Conclusion

The four imperfections I described above may explain why actual oil price paths diverge from the paths predicted by the Hotelling rule. In the next chapter I will look at one of these imperfections, namely the futures market, more closely.
Of course in order to work properly, the futures market must work efficiently. It should allow investors to set up and enforce contracts without transaction costs that are too high. Also it must allow investors to make transactions at each point in time in the future up to the point where the price of oil will be sufficiently high such that the market will no longer exist. In the next chapter I will see whether actual futures markets are efficient and if so, how well they do in explaining future oil price.

Chapter 4 – Oil futures markets

4.1 Introduction

Oil futures are traded on commodity exchange markets. They are agreements between a seller (e.g. an oil producer) and a buyer (e.g. a refinery) that specify when and how much oil will be bought or sold at a certain price stated in the contract. Both parties involved have an obligation to buy or sell, and therefore will only sign a futures contract if they agree about what the price will be at the specified time in the future. Therefore the settlement price of the contract will reflect expectations about future prices (although a risk premium is usually included to protect parties against market risk, i.e. the risk that the future spot price will differ from the price stated in the futures contract).

One of the most important markets where oil futures are traded is the New York Mercantile Exchange. The NYMEX Light Sweet Crude Oil futures contract, promising the delivery of 1,000 barrels of crude oil at the contracted price and date, serves as an international benchmark for pricing crude oil futures. Figure 4.1 shows the recent development of futures closing prices[3] :

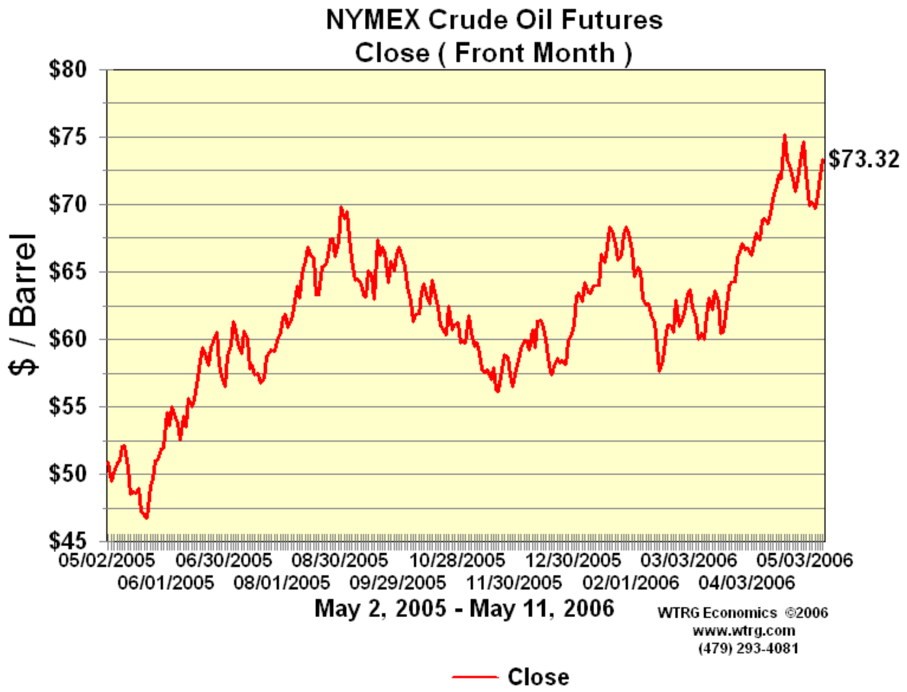

Figure 4.1 Recent future price development, WTRG Economics

In this chapter I will look at whether the futures market for crude oil is efficient, taking the NYMEX Light Sweet contract as a benchmark. The reason for this is the fact that this particular contract is, in relation to other contracts, highly liquid and can thus be traded fairly quickly and easily. It could therefore potentially be the most efficiently traded contract on the futures market for crude oil.

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[3] WTRG Economics, www.wtrg.com

However, even this relatively liquid type of futures contract may not meet the efficiency requirements made in Hotelling's model. As explained before, efficiency requires contracts to exist for all time horizons up to the point in time where the oil price equals the price of the backstop technology. In addition, even if futures markets appear to predict that prices will rise over time (as they have for the past decade), it is not entirely certain if such rising prices will actually materialize.

4.2 Short trading horizon

Next to having a relatively high degree of liquidity and price transparency, another requirement for efficiency in futures contracts is that it should be possible for parties to specify any future delivery date up to the point in time where the price of oil will rise above the price of the backstop technology. However, this is not the case for the Light Sweet Crude contracts. Only contracts with delivery dates up to six years in the future (i.e. December 2012 at the time this was written) are in fact traded [4]. This reflects the fact that futures contracts are mainly used for speculation or hedging purposes.

If a customer expects the price of crude oil to rise by the end of the year, he or she can buy a number of one-year futures contracts. Since futures are 'marked to market' (i.e. changes in the futures price are immediately settled between the two parties at the end of a trading day), if prices increase as expected, the contracts would provide the customer with a benefit. Instead, a decrease in the price would burden the customer with a loss.

Despite the existence of futures, most crude oil is still bought on the spot market. Especially, the oil deliveries specified in most future contracts never materialize as the contracts are 'rolled over' before the delivery date (Pindyck, 2001). This means that the customer would sell this year's contracts and buy new contracts for the following year as the delivery date draws near. Futures contracts are in this sense almost exclusively used as hedging or speculation instruments in order to decrease the risk of price fluctuations or earn a profit and not as a way to anchor the price for which oil will change hands in the future. It therefore makes sense that they are only traded over relatively short time horizons, unlike what would be required for efficiency from the point of view of the Hotelling model.

[4] New York Mercantile Exchange: Termination Schedule, http://www.nymex.com/lsco_fut_termin.aspx

4.3 Convenience yields

In addition to being only traded over short time horizons, the futures prices themselves may not be very suitable indicators from which to predict the behavior of future spot prices. Even if the prices stated in futures contracts are increasing, for example, it would be wrong to conclude from this that future spot prices are likely to show an increasing trend as well.
Haubrich et al. observe that oil futures prices are below spot market prices over 70% of the time (that is, the market is for the most part characterized by "backwardation") If futures would predict future spot prices, then this would imply that the market expects oil prices to fall 70% of the time. Looking at Figure 3.1, it can be seen that this is clearly not the case. The authors therefore argue that the prices of oil futures are not primarily determined by expectations, but rather by the storage economics that are inherent to the oil market.

Storing goods provides both costs and benefits. Storage costs are obvious and include for example the purchase or lease costs of silos or reservoirs as well as the fact that some goods (such as agricultural products) may spoil during storage. In the case of oil, storage costs are relatively low, since oil does not spoil and can most easily be "stored" by leaving it in the ground.
Storage benefits for oil, which primarily include "convenience yields" (i.e. the benefit of owning a good), are larger than just the price increase earned on the oil as a capital gain (as described in Hotelling's model). First, the option of being able to use the oil at any point in time is valuable. If future demand is uncertain, then it is easier and cheaper to have oil on hand in case of sudden demand shocks than having to buy the oil on the market. Secondly, due to price volatility in the short run, it is more convenient to postpone the exploitation of oil fields until a later point in time when prices may be higher. Leaving oil in the ground (that is, storing it in the cheapest way) provides oil producers with the option to continue to leave it there until prices increase to a desired level. This is more profitable than pumping up the oil beforehand, as storage costs are higher after extraction than before.
As Pindyck (2001) argues, holding oil in the ground can also be seen as holding a call option with a strike price that is equal to the costs of extraction and a potential gain of exercising equal to the oil spot price. If futures prices would be above the spot market price, every oil producer would postpone exercising their option, as doing so would be expected to increase payoffs in the future. Therefore in order for any oil production to take place now, future prices must be lower than spot prices.
Furthermore, the potential payoff of the call option (i.e. the convenience yield) is positively correlated with volatility of the spot price. Since oil price volatility is indeed high (as can be seen from Figure 3.1), futures prices are required to be substantially below spot prices. This is indeed what can be observed in the real market.

4.4 Conclusion

The time horizons over which futures contracts can be made in the real world is much smaller than efficiency requires from the point of view of Hotelling's model. Furthermore, because of convenience yields, futures prices do not reflect actual expectations about future spot prices. Instead they are determined through an arbitrage mechanism between present and future time periods. Therefore it would be wrong to rely solely on futures prices to infer whether oil prices develop according to the Hotelling rule.

Chapter 5 - Conclusion

It is clear that the historical price path has not developed in the way the Hotelling model would have expected it to do. The interest rate is not the only factor that shapes spot prices and how they develop over time. Technological change, new discoveries and market power are only some of the imperfections of the real market that make its behavior diverge from the model. In addition, most of these market imperfections are likely to be interdependent.
Futures markets do not prove to be very accurate in predicting whether future spot prices will follow the Hotelling rule due to the fact that the prices of futures are not primarily determined by investor's expectations but rather by convenience yields of storing oil.

In the presence of these market imperfections then, can the current extraction rate of oil still be called efficient? An efficient extraction path should be accompanied by rising prices over time. For most of the past century however, prices have been very volatile and have not followed any increasing or decreasing path. Does this mean that extraction is inefficient? More research in for example the area of extraction costs development over time and the formation of market expectations will be needed to answer this question.
Oil prices have been rising again over the past decade. If this trend continues in the years to come, than it will most likely pave the way to an increased adoption of alternative energy sources, as Hotelling's model predicts. However, peaks in the oil price have occurred before. It remains to be seen if oil prices will continue to rise.

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