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Abstract:

Everyone knows that oil discovered today, or that is newly allowed to be developed, such as in the Alaskan National Wildlife Refuge (ANWR), has no effect on prices until that oil hits the market. For instance, on its website, the Democratic Policy Committee, (http://democrats.senate.gov/~dpc/pubs/107-1-72.html) states that "it will require seven to twelve years from approval before there is any oil production from the ANWR area. Therefore, production in ANWR will have no impact on current or short-term gasoline and oil supplies and prices." While this is something that everyone seems to know, it is a case that the theory held by everyone just happens to be wrong.

Since future prices are expected to be lower, future profits are also lower, so the value of oil not produced now, but held for future sales, is lower, making it more profitable to go ahead and produce and sell now instead of waiting for future profits. Using oil now reduces the amount of oil available for the future, which involves the opportunity cost of forgone future profits, which are sometime called the marginal user costs or scarcity rents.

In this paper, we use simple two-period models to show that if an amount of newly discovered oil is significant enough to reduce prices in the future, any drop in future prices reduces the future profitability of oil, reducing the marginal user costs of oil now. That reduction in the marginal user costs reduces the current price of oil just as if there were a reduction in the marginal costs of extracting oil now. We explore the effects of the reduction in marginal user costs in the competitive or price-taker case as well as the price-searcher case, where a monopolist or dominant supplier responds to a substantial discovery by another seller, but where the discovery will not contribute to production for some years to come. In both cases, we find that oil that is expected to reach the market at some time in the future has an immediate impact on oil prices.

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1. Introduction

Everyone knows that oil discovered today, or that is suddenly approved for development, such as oil in the Alaskan National Wildlife Refuge (ANWR) will have no effect on prices until that oil hits the market. For instance, on its website, the Democratic Policy Committee (2006), (http://democrats.senate.gov/~dpc/pubs/107-1-72.html) states that "it will require seven to twelve years from approval before there is any oil production from the ANWR area. Therefore, production in ANWR will have no impact on current or short-term gasoline and oil supplies and prices." While this is something that everyone seems to know, it is another example that the theory popularly held happens to be wrong.

The economic theory of exhaustible resources is well developed and is presented in undergraduate textbooks on natural resource economics, such as presented in chapter's 2 and 5 of Tietenberg (1999). The concern over environmental issues and the oil crisis of the 1970s led to the development of the basic theory of exhaustible resources with Dasgupta and Heal (1974) and Solow (1974) providing our basic understanding. Lee (1978, 1979), for instance, uses this theory to show that price controls that are not currently binding may have resource allocation effects if the price controls would eventually be binding in the future, reducing future possible prices and profits, and so, reducing the opportunity cost of producing and consuming the resource in current period, and thus, increasing current consumption while reducing the current price. Conrad and Kotani (2005) take up a question that is related to ours, examining the trigger price for optimally drilling in ANWR, finding a trigger price that is well below current prices for oil. The trigger price they find, however, does not take into account the production and transportation externalities, nor the amenity values of the Refuge.

Using oil now reduces the amount of oil that will be available for the future. If this oil is not available in the future, profits cannot be made on this oil in the future and future profits not made because of the current use of the resource represent an opportunity cost of using the oil. With ANWR drilling allowed, future prices are expected to be lower making future profits also lower, and so the value of oil not currently produced and used, but held for future sales, is lower. This lower future profits means that the opportunity costs of going ahead and producing and using the oil now instead of waiting for future profits will also be lower. We call this opportunity cost of selling now instead of waiting to sell it sometime in the future the Marginal User Cost or the Scarcity Rent of the resource.

We use a simple two-period model (now and the future) to show that if an amount of oil that is discovered is significant enough to reduce prices in the future, that drop in future prices reduces the future profitability of oil, reducing the marginal user costs or the scarcity rents of oil now. That reduction in the marginal user costs reduces the current price of oil just as if there were a reduction in the marginal costs of extracting oil now. We explore the effects of the reduction in marginal user costs because of a discovery that will not contribute to production for some years to come in three scenarios:1) a monopoly scenario, 2) a scenario with a monopolist or dominant supplier who responds to a substantial discovery by another seller, and 3) a scenario with price taking or competitive producers. We find that oil that is expected to reach the market some years hence has an immediate impact on oil prices.

2. Two-period model

Consider a simple model of the market for oil with only two time periods, now and the future that we denote with subscripts 0 for the present and 1 for the future. For the sake of argument and simplicity, suppose that there is a finite quantity of a depletable resource, oil, that can be supplied because of natural limitations (this assumption makes things simple for us—there are various definitions of reserves that we could look at, and make assumptions around, but this is a simplifying assumption), so that $Q=q_0+q_1$, where Q is the total amount of oil available

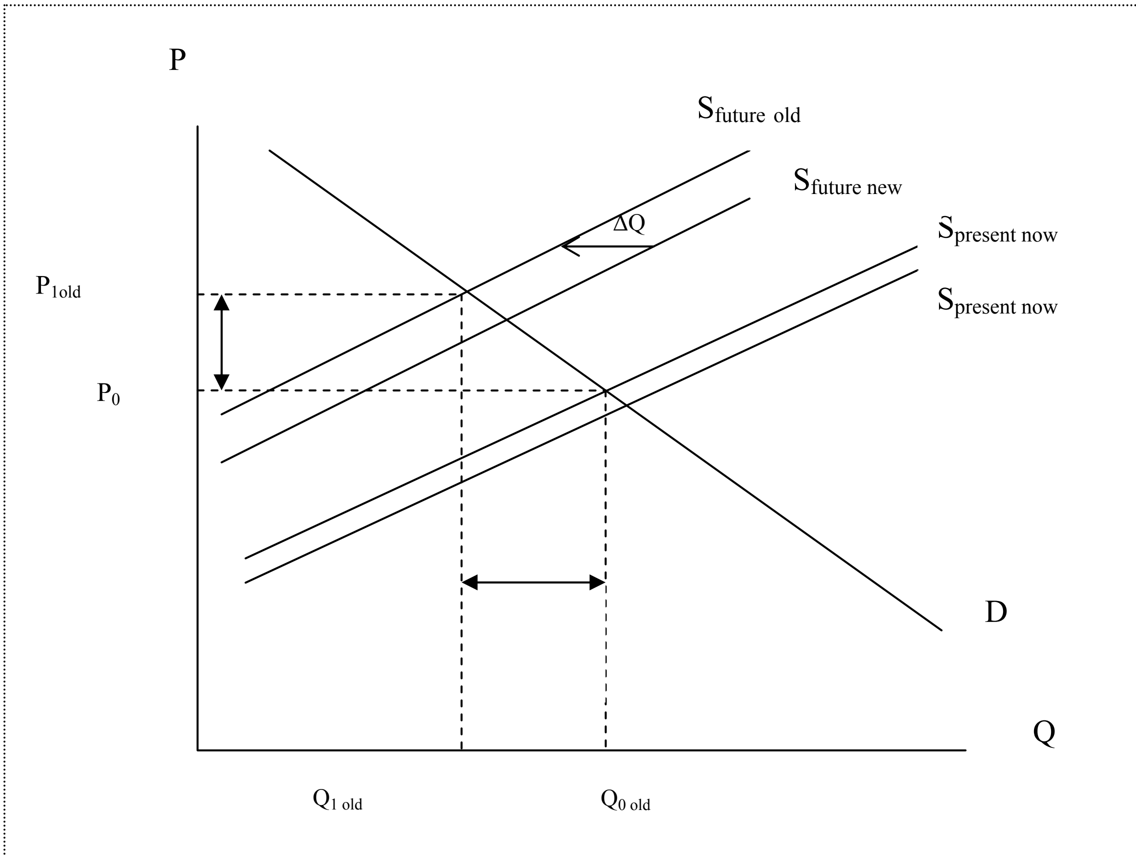


Figure 1

for the two time periods. There is some interest rate, r, we use to discount future values. The marginal cost of extraction is a constant, k, regardless of time or place. Further assume that it is cheap enough to pump oil out of the ground (the marginal extraction costs are sufficiently low) so that the scarcity rent or marginal user costs, forgone future profits on oil, are positive. The complete marginal cost of production is made up of two types of costs, the rather explicit costs of extraction and the scarcity rent or the marginal user costs, with the latter cost being an implicit cost of current production**.** There are two prices for oil to be concerned with, the present price, p_0, and the future price, $p_{1.}$ It is also assumed that there are no storage costs, that is, that the oil can merely be left in the ground and stored without costs except for the opportunity cost of the forgone profit that could be had now if the oil were pumped out and sold in the current period.

To keep from making matters overly and unnecessarily complicated, it is further assumed that the demand is the same, both now and in the future, and the current level of output, $q_{0,}$ is one that provides an equilibrium across the two time periods, such that firm profits are maximized across the two periods.

If the decision is made now to extract the oil in the Alaskan National Wildlife Refuge (ANWR), those particular barrels of oil will not be available until the future, as it takes some time to construct and put into place the necessary equipment and pipelines and begin pumping operations. Let's suppose that the ANWR oil, q_a, increases the oil available in the future period by 10 units, so that the total available oil in both periods changes from Q, what we initially thought the total amount of oil to be, to $Q + q_{a,}$.

2.1 *Monopoly Market*

Let the inverse demand for oil be D: p = a – bq in each period, so that if $\Delta q_1 = 10$, then the price in period 1 would drop by 10*b. If this happens, the profits in period 1, the future, will drop substantially and the opportunity cost of taking oil out of the ground in the 1st period drops, and more oil is pumped out not only in period 1, but also in period 0, the present. Some of the oil that would have been extracted in the future for which production facilities and pipelines are in place gets extracted in the present because of the expected reduction of oil prices in the future.

$$\Pi = aq_0 - bq_0^2 - kq_0 + \frac{1}{1+r}\left(aq_1 - bq_1^2 - kq_1\right) \tag{1}$$

Set $h = a - k$ and $g = \frac{1}{1+r}$ so that

$$\Pi = hq_0 - bq_0^2 + g\left(hq_1 - bq_1^2\right) \tag{2}$$

and recalling that initially

$$Q = q_0 + q_1, \text{ or that } q_1 = Q - q_0. \tag{3}$$

Setting this up as a simple Lagrangian problem, we have

$$L = hq_0 - bq_0^2 + g\left(hq_1 - bq_1^2\right) + \lambda(Q - q_0 - q_1) \tag{4}$$

and taking first derivatives and setting them equal to zero, we have

$$\begin{aligned} \frac{dL}{dq_0} &= h - 2bq_0 - \lambda = 0 \\ \frac{dL}{dq_1} &= gh - 2gbq_1 - \lambda = 0 \\ \frac{dL}{d\lambda} &= Q - q_0 - q_1 = 0 \end{aligned} \tag{5}$$

Solving the first two equations of (5) for λ, solving for the two q's and then substituting $Q - q_0$ for q_1, maximum profits occur where

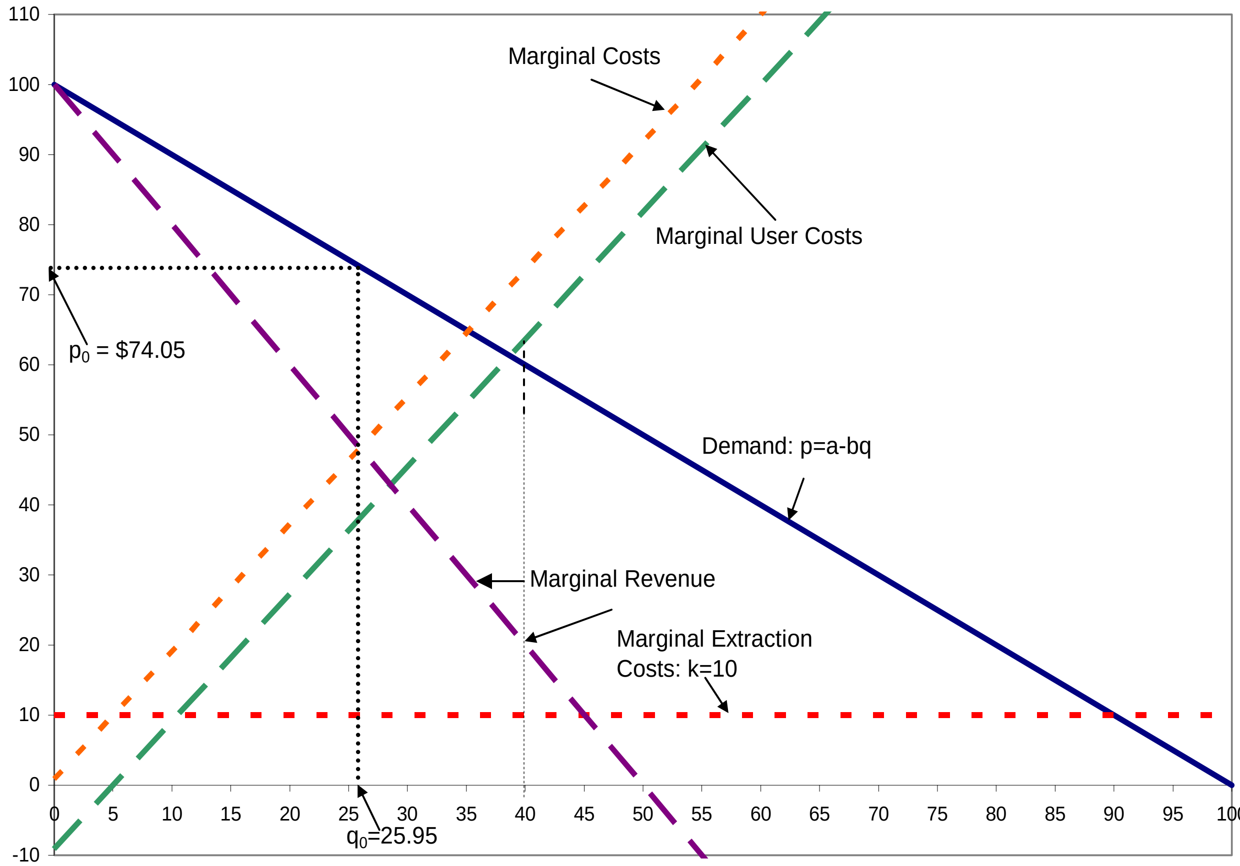
$$q_0 = \frac{h - gh + 2bgQ}{2b(1+g)} \quad \text{and} \tag{6}$$

$$q_1 = Q - \frac{h - gh + 2bgQ}{2b(1+g)} \tag{6a}$$

Suppose now that a discovery is made in the current period that we are certain will yield an extra 10 units of output, but that these particular 10 units will not be available until the future. The parameters we will use for illustrative purposes are: a = 100, b = 1, k = 10, Q = 50, q_a = 10, and r = 0.1. In Figure 2 we show the results of our two-period maximization problem.

Unless more oil is produced today, those extra 10 units of output from the new discovery would add 10 units of output in the future which would depress future prices by $10 in the future (the slope on demand is just -1), pushing prices in the future to $65.95. With 34.05 units of output in the future, the last unit of output, from 33.05 to 34.05 units, gives us a marginal user cost of $33.9, and so a marginal cost of $43.9 in the present, but the marginal revenue in the present at 25.95 units is $48.10, which suggests that the producers will expand output not only in the future, but in the present as well.

Figure 2



The least obvious element of Figure 2 is the Marginal User Cost that is shown as an upward sloping line with a price axis intercept of approximately -$10. To help understand what marginal user costs is about, think about the profits possible in the future period if $q_0 = 40$. If that were the case, the quantity available in the future would only be 10 units, so that the 40^{th} unit drilled and consumed in the present means giving up the 11^{th} unit in the future. That 11^{th} unit would have commanded a price of $89 in the future and would have added $78 to revenues and $10 in extraction costs, or $68 to profits, with a present value of $61.82, which is the Marginal User Costs for the 40^{th} unit of output in the present. If we add the two marginal costs, the marginal user costs and the marginal extraction costs, the Marginal Cost of the 40^{th} unit pumped and consumed in the present would be $71.82. Given the Marginal Cost and the Marginal

Revenue in Figure 2, or the substituting the parameters above into equation 6, the profit-maximizing quantity in the present is 25.95 units, and so, the profit-maximizing quantity in the future is 24.05 units. Likewise, the profit-maximizing prices are $74.05 in the present and $75.95 in the future.

With oil completely monopolized (including any new discovery), the total global quantity of oil will be taken into account in the maximization, that is, we can treat all 60 units as being considered by the firm. Under this case, the maximization problem is essentially the same we began with the Lagrangian in equation (4) which yielded an optimum q_0 in equation (6) of

$$q_0 = \frac{h - gh + 2bgQ}{2b(1+g)} \text{, so} \tag{6}$$

increasing Q by 10 gives us 30.72, so that a change in Q of 10 yields an extra 4.762 in the first period, or 30.72. Since the price falls one for one with rises in a period's price, the price in the first period will fall by $4.76 in the first period due to the increase in output.

2.2 *Dominant Firm Market: A Price Maker and a Future Price Taker*

Now, we consider the profit maximization problem for a large oil exporter, such as Saudi Arabia, making output decisions given changes in output decisions of another potential producer, but still a net demander of oil, such as the U.S. There is one oil market, with a worldwide demand, price and quantity. In the current period, the U.S. is producing no oil, but might be a producer in the future.

Suppose that the Saudis have complete control over the 50 units of oil that is known to exist at the beginning of the present period (time 0), but no control at all over the oil discovered during the present period and that will only be available in the future (time 1), a quantity that we will call q_a. Then the Saudis would want to maximize their two-period profits, but treat both Q and q_a as constants. The Lagrangian that the Saudis consider in their constrained maximization problem, then, would be

$$L = hq_0 - bq_0^2 + g\left(hq_1 - bq_1^2 - bq_a\right) + \lambda(Q - q_0 - q_1)\,. \qquad (7)$$

Taking the appropriate first derivatives and solving for q_0, we have

$$q_0 = \frac{h - gh + 2bgQ + gbq_a}{2b(1+g)} = \frac{99.90909 + 9.0909}{3.81818} = 28.33\,, \qquad (8)$$

which is up from the 25.95 units for q_0 above, and so the price is \$71.67 in the present, down from \$74.05. Note that differentiating (8) with respect to q_a results in

$$\frac{dq_0}{dq_a} = \frac{gb}{2b(1+g)} = \frac{g}{2(1+g)} = \frac{.90909}{3.81818} = 0.238095 \qquad (9)$$

which is the change from 25.95 that one would expect with $dq_a = 10$. Even though the new oil find will not produce oil until the future, its impact on prices is immediately felt in the market.

2.3 *Competitive Market*

If the sales of oil were more competitive, marginal revenue and price are the same because sellers are all price takers. So in the future period, marginal user cost is the discounted marginal future profit given up from each unit of output consumed in the present. Marginal user cost, then, is

$$MUC_0 = g(a - bq_1 - k) = g(h - bQ + bq_0) \qquad (10)$$

and since price is equal to marginal cost in perfect competition, we have

$$P = a - bq_0 = k + g(h - bQ + bq_0) = MEC + MUC \qquad (11)$$

so that the profit maximizing level of optimal in the present period is

$$q_0 = \frac{h - gh + bgQ}{b(1+g)} = \frac{\left(1 - \frac{1}{1+r}\right)(a-k) + \left(\frac{1}{1+r}\right)bQ}{b\left(\frac{2+r}{1+r}\right)} \qquad (12)$$

so that with a total of 50 units across the two periods, the present period quantity from (12) is q_0=28.095 while the future period quantity is q_1=21.905, and the prices would be p_0=71.905 in the present and p_1=78.085 in the future. If the total quantity across the two periods is expanded by 10 so that Q=60, then the present period quantity expands to q_0=32.857 while the future period quantity goes up to q_1=27.143, and the prices would be p_0=67.143 in the present and p_1=72.857 in the future period. Again, even though the new oil find will not produce oil until the future, its impact on prices is immediately felt in the market, with both the future price falling by $5.23 and the present price falling by $4.76, which was the same decrease in price we saw under the monopoly case.

3. Conclusions

Whether the market is monopolized by a single producer, dominated by one producer with another producer who acts as a price taker, or is competitive, increases in future output capabilities because of current discoveries will lead to lower prices in the future and so, a lower opportunity cost of using those resources in the present. ANWR production is likely to be small relative to world production, and we doubt that ANWR production, by itself, would do much to reduce current prices. On the other hand, if oil firms were allowed to drill in ANWR and many of the other areas that are currently off limits to oil production, it is possible that these areas together might have a significant impact on world oil prices.[1] We must also recognize that because of the extreme inelasticity of oil demand, small percentage increases in output lead to much larger percentage decreases in prices. While we are not advocating the current use of ANWR or off-shore areas currently off limits, neither are we advocating keeping ANWR and

[1] To the extent that opening ANWR to development signals a shift in U.S. energy policy, making it appear more likely that other off-limit areas would also be developed, the impact of opening ANWR might then be enough to have an impact on future and current prices.

other areas untouched and unused forever. Instead, we only hope to make clear the implications of opening such areas to energy development.

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