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A Fallacy in the ANWR Drilling Debate: A Lesson on Scarcity Rents and Intertemporal Pricing under Different Market Structures

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Abstract

It is common knowledge that oil discovered today, or that is newly allowed to be developed, has no effect on prices until reaching the market. However, economic theory does not support common knowledge on this issue. By lowering the value of holding oil for future sale, a future oil supply increase makes it more profitable for firms to produce and sell oil presently. Under three distinct market structures, we use a two-period model to show students that the resulting increase in present supply decreases the present price of oil. Production decisions in the absence of scarcity rents are also discussed.

KEYWORDS: pricing, ANWR, depletable resource regulation, scarcity rents

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I. Introduction

It is common knowledge that oil discovered today, or that is suddenly approved for development, such as oil 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 (2006), 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.” On the other side of the political spectrum, Ben Lieberman (2005) of the Heritage Foundation noted on the Heritage website: “With oil currently at \$55 per barrel— an inflation-adjusted level not seen since the early 1980s—public support for opening ANWR is also stronger than in the past. Supporters should remember, though, that ANWR drilling is a long-term project, not a short-term solution. It will take at least seven years of work before the first barrel becomes available, and so ANWR will not affect current oil and gasoline prices.” Apparently, economic theory does not influence common knowledge on the topic of newly developable oil reserves.

The economic theory of exhaustible resources is well developed by Hotelling (1931) and is presented in undergraduate textbooks on natural resource economics (e.g., chapters five and seven of Tietenberg and Lewis, 2009; chapter sixteen of Perloff, 1999). The concern over environmental issues and the oil crisis of the 1970s led to further 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 there is the belief that price controls eventually bind the market from achieving equilibrium, expected future prices and profits fall. Lower opportunity costs, then, lead to more current consumption and production of the good and, therefore, a lower market price in the current period. Conrad and Kotani (2005) take up a question that is related to ours, examining the trigger price for optimally drilling in ANWR. Assuming the amenity value of lands affected by ANWR drilling to be somewhere between \$200 million and \$300 million, the authors find a trigger price that is well below current prices for oil. Similarly, Hahn and Passell (2008) perform cost-benefit analyses on drilling in ANWR and in previously off-limits Outer-Continental Shelf regions of U.S. coasts. Similar to Conrad and Kotani (2005), Hahn and Passell (2008) find that the costs of drilling are outweighed by the benefits of doing so in any reasonable estimate of amenity and non-use values of ANWR and the Outer-Continental Shelf.

Using oil now reduces the amount of oil available for the future so that future profits cannot be made on such oil. That is to say, future profits forgone because of the current use of the resource represent an opportunity cost of present

use of oil. With drilling allowed in ANWR and other government-protected areas, future prices, and therefore future profits, are expected to be lower. Thus, the value of all oil not currently produced and used, but held for future sales, becomes lower. Lower future profits mean that the opportunity costs of producing and using the oil now instead of waiting for future profits are also lower. This opportunity cost is called the “marginal user cost” or “scarcity rent” of the resource. It is important to note that this paper treats ANWR as a symbol for restricted (or undiscovered) oil reserves. Though many studies calculate (based upon estimated elasticities) that ANWR oil supply has a negligible effect on the world price of oil (Borenstein, 2005, Perloff and Whaples, 2008, Hahn and Passell, 2008), it is possible that the sum of all restricted oil reserves, in the ANWR or elsewhere, could have a significant impact on current and future world oil prices.

We use a simple two-period model (now and the future), in which all present and future market information is certain, 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 (present marginal user cost) of oil. In turn, the reduction in present marginal user cost reduces the current price of oil just as if there were a reduction in the marginal cost of extracting oil now. We explore the effect of such a reduction in marginal user cost within three distinct settings: 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 expected to reach the market some years hence has an immediate impact on current oil prices, regardless of assumed market structure (though market structure affects the extent of the effect).

II. 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 (present) and 1 (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 so that $Q = q_0 + q_1$, where Q is the total amount of oil available for the two time periods. There is some interest rate, r , which is used 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) that the scarcity rent or marginal user cost, forgone future profit on oil, is positive. The complete marginal cost of production is made up of two types of cost: the rather explicit cost of extraction and the scarcity rent or marginal user cost, with the latter cost being an implicit cost of

current production. There are two relevant oil prices within the analysis: the present price, p_0 , and the future price, p_1 . It is also assumed that there are no storage costs; that is, oil can merely be left in the ground and stored free of any explicit cost. To avoid making matters overly and unnecessarily complicated, it is further assumed that demand is the same, both now and in the future, and the current level of output, q_0 is one that provides an inter-temporal equilibrium, such that firm profits are maximized across the two periods. Figure 1 below depicts such a market scenario.

If the decision is made now to extract the oil in the Alaskan National Wildlife Refuge (ANWR), those particular barrels of oil do not become 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 us 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 $Q + q_a$.

Figure I: A Two-Period Model of the Oil Market with Newly Developable Reserves

2.1 Monopoly Market

Let the inverse demand for oil be $D: p = a - bq$ in each period. If $\Delta q_1 = 10$, then the price in period 1 decreases by $10 \cdot b$ and profits in future period 1 drop substantially. Thus, the opportunity cost of taking oil from the ground in the present period declines. More oil is pumped out not only in period 1, but also in period 0 (the present). Some of the oil that is to be extracted in the future, for which production facilities and pipelines are in place, is extracted in the present because of the expected reduction of oil prices in the future. The two-period maximand is

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

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

$$\Pi = hq_0 - bq_0^2 + g(hq_1 - bq_1^2). \quad (2)$$

Recall that

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

Setting this up as a simple Lagrangian problem, we have

$$L = hq_0 - bq_0^2 + g(hq_1 - bq_1^2) + \lambda(Q - q_0 - q_1). \quad (4)$$

Note that λ is the Lagrange multiplier. At its optimal value, it represents the additional firms can earn when the immediate stock of oil reserves increases by a unit. Taking first derivatives and setting them equal to zero, we have

$$\frac{dL}{dq_0} = h - 2bq_0 - \lambda = 0$$

$$\frac{dL}{dq_1} = gh - 2gbq_1 - \lambda = 0 \quad (5)$$

$$\frac{dL}{d\lambda} = Q - q_0 - q_1 = 0$$

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

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

and

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

Given these formulas, suppose that a discovery is made in the current period that we are certain yields 10 extra units of output, but that these particular 10 units are not available until the future. The parameters we 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 the two-period maximization problem. Unless more oil is produced today, the extra 10 units of output from the new discovery adds 10 units of output in the future, which depresses future prices by \$10 in the future (the slope on demand is just -1) and push future prices 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. However, the present marginal revenue at 25.95 units is \$48.10, which suggests that the producers expand output in the present as well.

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 this marginal user cost concept is about, consider the profits possible in the future period if $q_0 = 40$. If this is the case, the quantity available in the future is only 10 units, so that the fortieth unit drilled and

Figure II: A Monopolist's Production Decision with Newly Developable Reserves

consumed in the present implies giving up the eleventh unit in the future. That eleventh unit would have commanded a price of \$89 in the future and would have

added \$78 to revenues against \$10 in extraction costs, or \$68 to profits, with a present value of \$61.82, which is the marginal user cost for the fortieth unit of output in the present. If we add the two marginal costs, the marginal user cost and the marginal extraction cost, the marginal cost of the fortieth unit pumped and consumed in the present becomes \$71.82. Given the marginal cost and the marginal revenue in Figure 2, or 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 is 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 as was specified by the Lagrangian in equation (4), which yielded an optimum q_0 of

$$q_0 = \frac{h - gh + 2bgQ}{2b(1 + g)} \quad (7)$$

Therefore, increasing Q by ten units gives us 30.72 units of production in the first period, or an extra 4.762 units. Since the price falls one for one with rises in a period's quantity, the price in the first period falls by \$4.76.

One should note that prices in each period are subject to the interest rate. A monopolist who holds a fixed supply of oil and faces constant marginal cost produces oil such that marginal revenue net of marginal cost rises at the rate of interest over time. If the monopolist were to produce such that marginal revenue minus marginal extraction cost rose more slowly than the interest rate over time, the monopolist has an incentive to produce more in the present and store profits in an interest-bearing asset. This act, however, decreases present marginal revenue (price) and increases future marginal revenue (price) until marginal revenue minus marginal cost rises at the interest rate over time. If the monopolist produced such that marginal revenue minus marginal extraction cost rose faster than the interest rate over time, the monopolist has an incentive to hold oil presently, increasing present marginal revenue (price) and decreasing future marginal revenue (price) until marginal revenue minus marginal extraction cost rises at the interest rate. Thus, p_0 falls and p_1 rises as the interest rate increases. In a many-period monopolistic setting with constant marginal extraction cost, the price of a fixed reserve of oil rises exponentially over time. In other words, the monopolist produces developed reserves in the future only if the future expected price offsets the present value of selling oil today and obtaining (compounded) interest upon the sale.

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 the 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. 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 are known to exist at the beginning of the present period (time 0). However, they have no control at all over the oil discovered during the present period and that is only available in the future (time 1), a quantity that we call q_a . In this case, the Saudis maximize their two-period profits, while treating both Q and q_a as constants. The Lagrangian that the Saudis consider in their constrained maximization problem, then, is

$$L = hq_0 - bq_0^2 + g(hq_1 - bq_1^2 - bq_a) + \lambda(Q - q_0 - q_1). \quad (8)$$

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

$$q_0 = \frac{h - gh + 2bgQ + gbq_a}{2b(1 + g)} = \frac{99.90909 + 9.0909}{3.81818} = 28.33, \quad (9)$$

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

$$\frac{dq_0}{dq_a} = \frac{gb}{2b(1 + g)} = \frac{g}{2(1 + g)} = \frac{.90909}{3.81818} = 0.238095, \quad (10)$$

which is the change from 25.95 that one expects with $\Delta q_a = 10$. Even though the new oil find does 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 are competitive, then marginal revenue and price are the same, as all sellers are price takers in this scenario. In the future period for this case, then, the 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

$$MUC_0 = g(a - bq_1 - k) = g(h - bQ + bq_0), \quad (11)$$

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

$$P = a - bq_0 = k + g(h - bQ + bq_0) = MEC + MUC \quad (12)$$

so that the profit maximizing level of oil production in the present period is

$$q_0 = \frac{h - gh + bgQ}{b(1 + g)} = \frac{\left(1 - \frac{1}{1+r}\right)(a - k) + \left(\frac{1}{1+r}\right)bQ}{b\left(\frac{2+r}{1+r}\right)} . \quad (13)$$

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 are $p_0 = 71.905$ in the present and $p_1 = 78.085$ in the future. If the total quantity across the two periods is expanded by 10 units so that $Q = 60$, then the present period quantity expands to $q_0 = 32.857$, and the future period quantity goes up to $q_1 = 27.143$. The prices are $p_0 = 67.143$ in the present and $p_1 = 72.857$ in the future period. Again, even though the new oil find does not produce oil until the future, its impact on prices is immediately felt in the market. The future price falls by \$5.23 and the present price falls by \$4.76 in this case. Table 1 summarizes equilibria for different market scenarios, interest rates, and units of newly discovered oil reserve.

Market Structure, Conditions	Present Equilibrium	Future Equilibrium
Monopoly, $q_a = 0, r = 0.1$	$(P_0^*, Q_0^*) = (74.05, 25.95)$	$(P_0^*, Q_0^*) = (75.95, 24.05)$
Monopoly, $q_a = 0, r = 0.2$	$(P_0^*, Q_0^*) = (73.19, 26.81)$	$(P_0^*, Q_0^*) = (76.81, 23.19)$
Monopoly, $q_a = 10, r = 0.1$	$(P_0^*, Q_0^*) = (69.29, 30.71)$	$(P_0^*, Q_0^*) = (70.71, 29.29)$
Monopoly, $q_a = 10, r = 0.2$	$(P_0^*, Q_0^*) = (68.64, 31.36)$	$(P_0^*, Q_0^*) = (71.36, 28.64)$
Dominant Firm, $q_a = 0, r = 0.1$	$(P_0^*, Q_0^*) = (74.05, 29.95)$	$(P_0^*, Q_0^*) = (75.95, 24.05)$
Dominant Firm, $q_a = 0, r = 0.2$	$(P_0^*, Q_0^*) = (73.19, 26.81)$	$(P_0^*, Q_0^*) = (76.81, 23.19)$
Dominant Firm, $q_a = 10, r = 0.1$	$(P_0^*, Q_0^*) = (71.67, 28.33)$	$(P_0^*, Q_0^*) = (78.33, 31.67)$
Dominant Firm, $q_a = 10, r = 0.2$	$(P_0^*, Q_0^*) = (70.71, 29.09)$	$(P_0^*, Q_0^*) = (69.09, 30.91)$
Competitive, $q_a = 0, r = 0.1$	$(P_0^*, Q_0^*) = (71.91, 28.09)$	$(P_0^*, Q_0^*) = (78.09, 21.91)$
Competitive, $q_a = 0, r = 0.2$	$(P_0^*, Q_0^*) = (69.09, 30.91)$	$(P_0^*, Q_0^*) = (80.91, 19.09)$
Competitive, $q_a = 10, r = 0.1$	$(P_0^*, Q_0^*) = (67.14, 32.86)$	$(P_0^*, Q_0^*) = (72.86, 27.14)$
Competitive, $q_a = 10, r = 0.2$	$(P_0^*, Q_0^*) = (64.55, 35.45)$	$(P_0^*, Q_0^*) = (75.45, 24.55)$

Table 1: Present Equilibria with and without Future Supply Increase

One should note that prices in each period are again subject to the interest rate in the competitive equilibrium, so that $p_1 = p_0(1 + r)$. If the interest rate rises, for example, there is more incentive for firms to pump developed oil reserves today so as to keep more present revenues in the bank. In other words, an increase in the interest rate, *ceteris paribus*, increases the present supply of oil and therefore decreases the future supply of oil. Thus, p_0 falls and p_1 rises as the interest rate increases. In a many-period, competitive setting with constant marginal extraction cost, the price of a fixed reserve of oil rises exponentially over time. In other words, suppliers produce developed reserves in the future only if the future expected price offsets the present value of selling oil today and

obtaining (compounded) interest upon the sale. In general, the price of oil minus its marginal extraction cost rises at the rate of interest in a competitive market for oil. If price is expected to rise at a rate slower than the interest rate, there is an immediate rush to sell reserves such that prices adjust. If price is expected to rise at a rate faster than the interest rate, there is a reluctance to sell developed reserves such that prices adjust.

III. When future prices do not affect current prices

The previous models show that the present and future prices of oil are fundamentally related via the presence of scarcity rents. Why has this result not entered public discourse on the opening of protected oil reserves? Perhaps people are accustomed to thinking about goods and services for which future production does not rival present production (e.g., non-storable goods). As distinct from the case of a depletable resource, the current production of non-storable goods and services does not constrain future production. Therefore, there is no implicit scarcity rent which discourages the present production of such goods and services.

As an example, we can consider a government that announces its intention to lift a binding ban on income tax preparation by foreign firms. Assume that the new policy is effective one year from the date of the announcement. Such a move shifts the expected future supply curve for tax preparation within the country, as foreign tax firms contribute to future supply. Thus, the future price of professional tax preparation is expected to decline in the country. Domestic tax preparation firms face no scarcity rent in the present tax year. These firms continue to produce as if the announcement was never made, and the present market price of professional tax preparation does not change in response to the announcement.

Imagine that a country passes a freedom of press law that becomes effective at some point in the future. This law allows newspapers to provide more valuable material to readers. In other words, the expected future demand for newspapers is expected to rise, and the future price (profit) of newspapers is also expected to rise. This shift in future expectations does not affect the current price or quantity of newspapers. Like tax preparation, newspaper firms do not face scarcity rents. In the absence of present marginal user costs at any future newspaper price, the calculus of present market allocation of newspapers does not change.

Further, we might imagine a small, isolated town that possesses one restaurant. The town board decides to rezone a five-acre slab of land, effective one year hence, such that it can be used for commercial purposes. At least two more restaurants are expected to open once the rezoning becomes effective. Thus, we expect a higher future production quantity of restaurant services in the town at

a lower future price. However, as restaurant service and food stores are renewable, the present price and quantity of the service remain the same, *ceteris paribus*. As one final example, an increase in the number of accredited medical schools in the United States increases the supply of doctors ten years hence but does not, in the absence of scarcity rents, drive down the present price of medical treatment. There are many additional examples of markets in which expected future price changes do not affect current production decisions. When discussing intertemporal price relationships, we must remember to treat oil, and other depletable resources, as a special case of goods.

IV. 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 lead to lower prices in the future and so, a lower opportunity cost of using those resources in the present. This effect is most pronounced under the competitive market scenario and least pronounced under the monopoly market scenario. Therefore, oil that is newly discovered (or newly allowed to be developed) has an immediate, downward effect upon prices. Though the extent of this effect for a particular discovery may be debated, an informed policy discussion must recognize the effect of new discoveries or the lifting of development bans on current and future prices, and as Hahn and Passell (2008) suggest, on benefits and costs of development and use of domestic resources. As most goods and services are intertemporally non-rival in production (i.e., lack scarcity rents), policymakers can forget the role of scarcity rents in the intertemporal pricing of non-renewable resources. The lesson herein helps students understand the import and theoretical underpinnings of this distinction.

We treat ANWR as a symbol for restricted (or undiscovered) oil reserves. Though many studies calculate (based upon estimated elasticities) that ANWR oil supply has a negligible effect on the world price of oil (Borenstein, 2005, Perloff and Whaples, 2008), it is possible that the sum of all restricted oil reserves plus natural gas in the ANWR and elsewhere, might have a significant impact on current and future world oil 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 other areas untouched and unused forever. Instead, we only hope to demonstrate to students of economics the implications of opening such areas to energy development.

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