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PETROLEUM PRICE CONTROLS WHEN INFORMATION IS A JOINT PRODUCT*

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ABSTRACT

When price controls alter the production schedule from one crude oil property, they can indirectly alter production decisions at other properties not subject to controls, even if the two properties are not related by physical production or demand effects. This occurs if (i) the property under price controls produces information as a joint product, (ii) there is a jointness of information between the properties, and (iii) the existence of fixed costs of beginning development on the non-controlled property allows the availability of information to affect total equilibrium conditions.

I. INTRODUCTION

Federal regulations which set maximum price schedules for crude oil production are, without a doubt, a major reason for the recent increased interest in the effects of pricing policy on resource production. The papers of Burness [1976], Montgomery [1977] and Lee [1978] demonstrate that, due to the intertemporal nature of the fixed resource problem, price controls, even those which appear to be "nonbinding" in a static sense, will lead to altered production schedules by profit maximizing, competitive firms. In general, whether price controls lend to earlier or later resource depletion depends upon the rate of change of the spread between the world and controlled prices. Montgomery, based upon estimates of price behavior and of physical properties of oil fields, calculated that "if domestic oil producers had not been subject to price controls, and if they extrapolated recent OPEC pricing behavior, current (1977) U.S. oil production would be lower than it is now under price controls". The comparative statics of price controls is presented in Appendix I.

Standard economic theory suggests that when price controls alter the production of some good X, other goods which are related to X through production techology or market demand will also be affected. In this paper, I will show that there is another way in which production decisions on seemingly unrelated deposits can be biased by the existence of price controls on one of them. This occurs if (i) the property under price controls produces information as a joint product with the resource, and (ii) there is a jointness of information between the two properties, and (iii) the existence of fixed costs of beginning development on the non-controlled property allows the availability of information to affect total equilibrium profitability conditions.

Existing work has focused on the effects of price controls on the production schedule of the directly controlled commodity. Yet, such controls may distort economic signals to owners of other resources and serve to alter their production decisions. There are many obvious ways in which price controls on one commodity, X, can directly distort the production of another good, Y. First, X and Y may be joint products, or their production may entail common costs. Likewise, the demand for X and Y may not be independent. For example, the market for natural gas is connected in both respects to crude oil production. In some fields, natural gas and crude oil are joint products. And, natural gas and crude oil derivatives are imperfect substitutes for many fuel purposes.

There is also the possibility that regulations are written so as to bring Y under controls even though it is a different resource. For example, that most striking aspect of U.S. federal regulations has been the rather severe set of price controls placed on "old" oil, oil from "properties" already in production at the beginning of the OPEC price increase. Other U.S. production has either remained free from controls, or has been placed under a much higher ceiling price. Presumably, the controls on old oil are an attempt to strip away

intramarginal rent from owners of crude oil with lower marginal production costs. However, "property" was defined by the Federal Energy Administration to be "the right to produce domestic crude oil which arises from a lease or from a fee interest".[1] Yet, given input prices, production costs are determined by physical properties of the particular reservoir. But, if two reservoirs X and Y are covered by the same lease, production from them is classified together for purposes of determining old oil levels, even if production from reservoir Y is substantially more expensive than from X. On the other hand, if reservoir X extends beyond the "property" boundary, its oil can legally be produced at two different prices. The F.E.A. (now Department of Energy) has considered proposals to base the determination of old oil upon reservoir limits, but has dropped the idea because of the "enormous administrative problems associated with determining the limits of thousands of different reservoirs".[2]

This paper examines one other manner in which production schedules may be interdependent. Production from the price controlled site, may produce joint products: the resource X and information valuable to the production of Y. The next section presents a model where it is reasonable to suspect that changes in the flow of the external information from X will affect the production of Y.

II. INFORMATIONALLY RELATED PRODUCTION

Let us now consider specifically crude oil production. The basis for analysis, following federal procedures, will be the oil "property". Assume that the output of each property is identical in all physical aspects and that there are no differences in transportation costs. Let there be a single oil price trajectory, $\tilde{P}_t$, which is known and is determined exogenously (say, by a perfectly elastic supply price announced by the OPEC cartel). Furthermore, let the physical production functions of the oil from each property be independent. This second assumption is not made because it is necessarily a good description of reality. Rather, it was noted in the last section that problems can be caused by production interdependence. The purpose of this section is to demonstrate some potential distortions which can exist even in the absence of direct production jointness.

Next, suppose that there are two properties, X_s and X_v. X_s is subject to a price ceiling and its output schedule is different than in the absence of price controls. X_v is not subject to the price ceiling. By the above assumptions, the price of its output, $\tilde{P}_t$, and its production costs $C(x_v)$ are unchanged. Nevertheless, there is the possibility for the price controls on X_s to affect the production decisions for X_v. Suppose there is a jointness of information between the two properties(in that production data from X_s also provide information about X_v) and the existence of fixed costs for well development of X_v allows the availability of such information to affect the total equilibrium conditions. If price controls on X_s lead to a change in the X_s production schedule, the flow of the external information about X_v will also be altered. The change in this external information flow can affect the total profitability decision of commencing development on X_v. A simple example follows.

Suppose there is ϕ probability that X_v will produce X^1 oil, and $(1-\phi)$ probability that it will produce nothing. The discounted expected profits of developing the property starting today (when the true state will be revealed only after initial development is completed) are

$$\phi\left(\int_{t_o}^{\infty}\left\{\tilde{P}_t x^*_{vt} - C(x^*_{vt})\right\} e^{-\gamma t} dt\right) + (1-\phi)(0) - F \tag{1}$$

where

x^*_{vt} = the optimal output in period t if there is X^1 oil

γ = discount rate

$C(x_{vt})$ = production costs

F = an initial fixed cost of commencing development

As noted, F is some initial fixed development cost (such as constructing roads, locating a water supply, providing drilling equipment, etc.) which must be incurred before any extraction. If development is to be started today, t_o, then F has to be paid while the true amount of oil is uncertain.

However, beginning development today might not be optimal. Firms must consider the global condition of when to begin development. The value of (1) may, in fact, be negative. Instead, development might optimally be delayed until time t_1 when the firm knows that it will receive a free signal which will disclose, with certainty, whether there is X^1 or no oil in the property. Then, (discounting to today by $\beta^{(t_1-t_o)}$) the expected value of this development plan is

$$\beta^{(t_1-t_o)}\left(\phi\left[\int_{t_1}^{\infty}\left\{\tilde{P}_t x^*_{vt} - C(x^*_{vt})\right\}e^{-\gamma t}d_t - F\right]\right) \tag{2}$$

which can be positive even if (1) is negative because by waiting until t_1, the firm can avoid expending F until and unless it knows for sure that X^1 oil exists.

It is at this point that the information connection between X_v and X_s should be clearly important. Suppose the signal at t_1 is generated by the production from X_s. That is, production from X_s yields joint products: oil and information about X_v. A price control regime which alters the production of X_s will also alter the production of information about X_v. But information about X_v is valuable to the firm, and the decision to begin development can depend upon it. Even though price controls on X_s do not alter the marginal profitability conditions for X_v, they can affect the total conditions. Specifically, if production from X_s is speeded up, the firm which owns X_v may hasten the initial development date as the flow of information about X_v is quickened.

Changing from discrete to continous uncertainty over reservoir characteristics does not change the principle outlined in this

section. Nor do we have to restrict consideration to information which reveals the state of the world with certainty. All that is needed is that the firm prefer to wait for some future valuable information before beginning development. However, the result is vacuous if there is not, in general, information about X_v which is producted jointly with x_s either because analogy comparisons are not valid, or because such information is not related to the production schedule. In fact, it appears that firms do use historical production data from more mature properties in estimating reserves at other prospects. In the Petroleum Exploration Handbook by Moody [1961] the use of "analogy" reserve estimation is discussed;

> Production statistics and reservoir data are available on older fields, thus enabling the geologist or engineer to calculate actual cumulative recoveries in barrels per acre or barrels per acre-foot for any given field or reservoir. Nothing is of more value to the estimator than historical knowledge of a similar reservoir. However, these statistical yardsticks should not be used as a substitute for judgment, but as tools to make judgment more accurate.

In particular, cumulative recovery data, focusing on the pressure of the "drive" in the formation, are said to be useful in reserve estimation.

It should be noted that the information from X_s about X_v may be, but need not be, a message which is external to a firm. If the message is not external to a firm (because the same firm owns both properties) it should be argued that in planning production from X_s, the value of message about X_v is included in the calculations. In Appendix II, it is demonstrated that the result that price controls alter production incentives for the X_s property remains, although under some circumstances the way in which production is rescheduled may vary if the information is included in the calculations.

Finally, this exposition has been presented in terms of "development". Using this terminology is not meant to exclude activities which are commonly called "exploration". To the extent that oil firms make the same information - sensitive calculations in timing of oil exploration, the same conclusions are applicable.

Price controls can affect the pattern of exploration on non-controlled prospects if the timing of the exploration relies upon information generated as a joint production of the (altered) production schedule of the price controlled wells.

III. CONCLUSION

There are many ways in which price controls on one oil property can bias the production decisions at a second property. The direct effects through production and demand dependence are straightforward. There are undoubtedly other areas, such as changes

in price expectations or gaming against the controls themselves, which still need to be examined. This paper has shown that the distortion of information flows is also a possibility. While no attempt has been made to quantity or rank the various effects, it seems that the use of inter-property analogy in petroleum exploration is considered important by petroleum geologists.

APPENDIX I

The following is adapted from Burness [1976] and Montgomery [1977].

Let

$\tilde{P}_t$ = world oil price trajectory, determined exogenously by O.P.E.C.

P_c = controlled price of domestic crude oil (assumed constant over time)

define $\alpha_t \equiv (\tilde{P}_t - P_c)$

Rewrite $\tilde{P}_t$ as $P_c + \alpha_t$

γ_t = market discount rate

x_t = production of petroleum in period t

$C(x_t)$ = production costs

X_t = resource remaining in period t

The problem for the expected profit maximizing firm can be considered a problem of optimal control. In the case of price control, the problem is to

$$\max_{x_t} \int_{t_o}^{T^1} \left\{ P_c x_t - C(x_t) \right\} e^{-\gamma t} dt$$

subject to $\dot{X}_t = - x_t$

The Hamiltonian to be formed is

$$H^1 = \left\{ P_c x_t - C(x_t) \right\} e^{-\gamma t} - \lambda_t^1 x_t$$

the necessary conditions are

a.i) $$\frac{\partial H^1}{\partial x_c} = 0 = P_c - C'(x_t) - \lambda_t^1 e^{\gamma t}$$

$$\Longrightarrow \quad P_c - C'(x_t) = \lambda_t^1 e^{\gamma t}$$

a.ii) $$\frac{\partial H^1}{\partial x_t} = -\dot{\lambda}_t^1 = 0$$

a.iii) $$\lim_{t \to T^2} \left\{ \left(P_c x_t - C(x_t) \right) e^{-\gamma t} - \lambda_t^1 x_t \right\} = 0$$

Likewise, the expected profit maximizing firm which receives the uncontrolled price for its output will act to

$$\underset{x_t}{\text{Max}} \int_{t_o}^{T^2} \left\{ (P_c + \alpha_t) x_t - C(x_t) \right\} e^{-\gamma t} dt \quad \text{subject to } \dot{X}_t = -x_t$$

The Hamiltonian is

$$H^2 = \left\{ (P_c + \alpha_t) x_t - C(x_t) \right\} e^{-\gamma t} - \lambda_t^2 x_t$$

and the necessary conditions are

b.i) $$\frac{\partial H^2}{\partial x_t} = 0 = (P_c + \alpha_t) - C'(x_t) - \lambda_t^2 e^{\gamma t}$$

$$\Longrightarrow \quad (P_c + \alpha_t) - C'(x_t) = \lambda_t^2 e^{\gamma t}$$

b.ii) $\frac{\partial H^2}{\partial x_t} = -\dot{\lambda}_t^2 = 0$

b.iii) $\lim_{t \to T^2} \left\{ \left((P_c - \alpha_t)x_t - C(x_t) \right) e^{-\gamma t} - \lambda_t^2 x_t \right\} = 0$

Since the firm faces the same resource constraint in each case, there must be at least one point at which the production schedules intersect. Denote x_{tc} as production at time t with controls, x_{tw} as production at time t when the firm faces world prices. Totally differentiating a.i and b.i results in

$$\dot{x}_{tc} = \frac{-\gamma\left(P_c - C'(x_{tc})\right)}{C''(x_{tc})} \qquad \text{A.I.1}$$

$$\dot{x}_{tw} = \frac{\dot{\alpha} - \gamma\left(P_c + \alpha - C'(x_{tw})\right)}{C''(x_{tw})} \qquad \text{A.I.2}$$

Let $\hat{t}$ be one such time at which the production schedules intersect, so $x_{\hat{t}c} = x_{\hat{t}w} = x_{\hat{t}}$. At time $\hat{t}$

$$\dot{x}_{\hat{t}c} - \dot{x}_{\hat{t}w} = \frac{-\dot{\alpha} + \gamma\alpha}{C''(x_{\hat{t}})} \qquad \text{A.I.3}$$

which is positive, negative, or zero as γ is greater than, less than, or equal to $\frac{\dot{\alpha}}{\alpha}$, the proportunate rate of change of the difference between the world price and the price ceiling. If $\dot{x}_{\hat{t}c}$ is less than $\dot{x}_{\hat{t}w}$, the price control production schedule intersects the market price production schedule firm above. If $\frac{\dot{\alpha}}{\alpha}$ is always greater than

γ, the rate of interest, there will be only one intersection point. In this case, production under price controls is initially greater than in a free market, and resource exhaustion occurs sooner. If the relationship between $\frac{\dot{\alpha}}{\alpha}$ and γ varies, but $\frac{\dot{\alpha}}{\alpha}$ is greater than γ at the first intersection point, then production rates before that point are greater under price controls, but the ultimate exhaustion date may be sooner or later.

APPENDIX II

Suppose the firm recognizes that production from X_s yields another good, information. Denote $f_c(x_t)$ as the value of information received from production x_s at time t when there are price controls. Let $f_w(x_t)$ be the value when there are no price controls. At time $\hat{t}$, defined as in Appendix I as a time at which the production schedules intersect, the analagous equation to A.I.3 is

$$\dot{x}_{\hat{t}c} - \dot{x}_{\hat{t}w} = \left[\frac{-\gamma\left(P_c - C'(x_{\hat{t}})\right) - \gamma\left(f_c'(x_{\hat{t}})\right)}{C''(x_{\hat{t}}) - f''_c(x_{\hat{t}})}\right] - \left[\frac{\dot{\alpha} - \gamma(P_c + \alpha - C'(x_{\hat{t}}) - \gamma\left(f_w'(x_{\hat{t}})\right)}{C''(x_{\hat{t}}) - f''_w(x_{\hat{t}})}\right]$$

If price controls do not change the value of the information, perhaps because (as was assumed in section III) $\tilde{P}_t$ is exogenous, then

$\dot{x}_{\hat{t}c} - \dot{x}_{\hat{t}w} = \dfrac{-\dot{\alpha} + \gamma\alpha}{C''(x_{\hat{t}}) - f''(x_{\hat{t}})}$ which yields exactly the same conditions as A.I.3 as long as $C''(x_{\hat{t}}) > f''(x_{\hat{t}})$.

FOOTNOTES

41 Federal Register 4940, February 3, 1976.

41 Federal Register 4938, February 3, 1976.

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