SYNFUELS PRODUCTION, EXHAUSTIBLE RESOURCES AND MONOPSONY POWER

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Abstract

We examine government intervention in the production of synthetic fuels for a nation with monopsony power in the market for an exhaustible resource. A Stackelberg game involving the government and resource producers is analyzed. In some cases, optimal synfuels capacity is found to be unprofitable even at the margin. In the absence of uncertainty, a commitment to build and operate a synfuels plant is shown to be superior to building one with the option of closing or mothballing it.

1. Introduction

Over the past decade there has been considerable debate as to the appropriate role of government in exhaustible resource markets. The controversy surrounding the Synthetic Fuels Corporation has renewed the debate over whether governments should promote the development and production of substitutes for imported exhaustible resources such as oil. Many types of economic issues often get raised: advocates of government intervention may point to external (national security) benefits from the production of substitutes; or they may cite the large capital requirements for developing certain substitute fuels (for example, oil shale) and suggest that private capital markets will be unable to provide for sufficient investment at the appropriate discount rate; or they may refer to the public goods nature of R&D and maintain that private firms will invest insufficiently in the acquisition of knowledge.

Another important argument concerns monopsony power. For a nation that generates a significant fraction of the world demand for conventional fuels, the development of substitute resources can exert some downward pressure on their prices. The benefits to domestic consumers from a reduction in imported oil prices would not be taken into account in the profit-maximizing decisions of private firms contemplating synfuels production; this suggests that government involvement may be necessary to bring about the optimal level of synfuels production (from the importing nation's point of view). The monopsony power issue has significance regardless of whether the world oil market is dominated by a cartel or is purely competitive, since in either case, synfuels production can potentially lower the path of conventional fuel prices.

Monopsony power arguments are often cited as justifications for tariffs on imported oil. In fact, many would regard an oil tariff policy as superior to a subsidy program as a means of lowering imported oil prices (net of tariff) and enhancing social welfare. The argument is that, under the optimal tariff policy, consumers and domestic producers of both oil and synthetic fuels would face the "true" opportunity cost of importing oil, and that market forces would then determine the appropriate levels of production and consumption.[1]

Yet certain considerations indicate that it might be difficult to enforce the type of "optimal" tariff policy which would constitute a serious alternative to a synfuels program. An important issue concerns the difficulty which an importing country may have in commiting itself credibly to an optimal tariff program. As pointed out by Newbery [1975] and Maskin and Newbery [1978], it is often in the government's interest not to abide by the "optimal" tariff program which it announces. The solution of the optimal tariff problem is not dynamically consistent (in the sense defined by Kydland and Prescott [1977]). This adversely affects the government's credibility, and can lead to preemptive behavior on the part of oil producers with adverse welfare implications.

Given the difficulties associated with certain tariff programs, it seems worthwhile to reconsider the potential of certain subsidy programs. In this paper we explore how monopsony power might be explicited by subsidizing a substitute for an imported exhaustible resource. We examine this issue using oil as the exhausible resource and synthetic fuels (synfuels) as the substitute, but the analysis is more general.

We are especially interested in whether some of the commitment difficulties associated with tariffs can be evaded by a synfuels subsidy. We consider the potential for dynamic inconsistency under the subsidy program and the circumstances under which precommitment or inflexibility may offer advantages.

We begin our paper by examining the optimal level of synfuels production for an importing country with monopsony power. Our approach is formally similar in certain respects to that of Dasgupta, Gilbert and Stiglitz [1981], who concentrate on the optimal timing of introduction, rather than the optimal quantity produced, of a substitute resource. We shall consider the case where the imported resource is supplied by a cartel behaving as a profit-maximizing monopolist, and the case where suppliers are perfectly competitive. The government is assumed to commit itself credibly to the production of synfuels at some time in the future. The cartel or competitive producers maximize profits as a function of the level of synfuels production; propositions concerning this decision are developed in part A of Section 2 below. Realizing this dependence, the government optimizes the level of synfuels production; part B of Section 2 is devoted to an analysis of this decision.

In this paper, we regard synfuels as a perfect substitute for conventional resources, which are treated as exhaustible. The implications of the development of a substitute resource for an exhaustible conventional resource have been investigated by other authors. In many studies (e.g., Nordhaus [1973]), the substitute is regarded as a "backstop technology" available in unlimited quantities at or above some "backstop price". In our analysis of synfuels, we do not assume a backstop technology; instead, we explicitly concern ourselves with the issue of the quantity of synfuels which should be made available. Given the long lead times, large capital requirements, and perhaps the exhaustibility of the synthetic fuel itself, this seems a reasonable approach. The limited availability of synfuels raises the possibility of market sharing between synthetic and conventional fuels. One of the issues we examine is the conditions under which market sharing will occur.

In Sections 3 and 4, we consider the value of the government having the option to close the synfuels plant or postpone its operation. The central result of this paper is that flexibility with respect to production of synfuels, in the absence of uncertainty, will often hurt, and almost never help, the importing government.

The final section summarizes the results and discusses their significance.

2. The Model

We present here a partial equilibrium model in which the principal economic agents are foreign producers of an exhaustible resource and domestic producers of a synthetic substitute fuel. The case of exhaustible resource production by a cartel which acts as a profit-maximizing monopolist, as well as that of perfect competition among the resource producers, will be considered here. In this section we employ the model to explore the effects of government synfuels activity on the production decisions of owners of the exhaustible resource. We then examine what constitutes optimal synfuels production from the point of view of the importing country.

Here synfuels do not represent a "backstop technology," since the quantity of synfuels available is limited by plant capacity, rather than infinitely available at or above some backstop price. We are explicitly concerned with the implications of the choice of plant capacity.

The date of introduction of the synfuel is exogenous: synfuel production begins at some future date, T, and continues for all time after T.[2] This treatment contrasts with that of Dasgupta, Gilbert and Stiglitz [1981], who treat the date of introduction as a policy variable but regard the substitute resource as a backstop technology.

The presence of synfuels — and, in some cases, the mere capacity to produce them -- affects the pricing strategy of resource producers, whether the latter are competitive or loyal to a cartel. Since synfuels are perfect substitutes for the exhaustible resource, additional production of synfuels increases the quantity of fuels (exhaustible resources plus synfuels) available and lowers the price which exhaustible resource suppliers can obtain for a given aggregate quantity of the resource. We regard the government as a Stackelberg leader: it takes into account the effect of the level of synfuels production on the pricing decisions of the resource producers.

The government represents an importing country which is regarded as the sole demander of the exhaustible resource and of the substitute, synthetic fuels. We assume that synfuels plants are built and operated by the government.

Define z_t as the quantity of the exhaustible resource made available by foreign producers at time t, and define q_t as the total quantity of the exhaustible resource and the synfuel available at that time. When the government is committed to operating its synfuels plants at capacity, the quantity of synfuels available will be y,[3] once the plants are operational. Thus

$$(1) \qquad q_t = \begin{cases} z_t, & 0 < t < T \\ z_t + y, & T \le t < \infty \end{cases}$$

The demand for all fuels (the exhaustible resource plus synfuels) is given by the continuously differentiable function:

$$(2) \qquad q = f(p) > 0$$

where p is the price of fuels. It is assumed that $f'(p) < 0$. We define $p(q) \equiv f^{-1}(q)$. For analytical convenience, we make the assumption throughout that $f(p)$ is constant over time and independent of demand and price in other periods.[4]

We shall arrive at an optimal level of synfuels production in two steps. First, we examine the response of resource producers to given values of y. Then we search for an optimal level of y, taking into account the response of resource producers.

A. The Resource Producer's Decision Problem

1. Cartel Case

Resource producers are regarded as attempting to maximize discounted profits. The resource is assumed to be costless to extract.[5] The initial stock of the resource is designated as S_0. When the resource suppliers belong to a cartel, the maximization problem is:

$$\max_{\{z\}} \int_0^T z_t\, p(z_t)\, e^{-rt}\, dt + \int_T^\infty z_t\, p(z_t+y)\, e^{-rt}\, dt \tag{3}$$

subject to

$$\int_0^\infty z_t\, dt < S_0$$

This represents a special case of the standard optimal extraction problem for monopolistically-owned exhaustible resources. Here the monopolist faces different stationary demand functions in the intervals $[0,T)$ and $[T,\infty)$. The demand function from $[T,\infty)$ is the one from $[0,T)$ shifted leftward by the quantity y.

The extraction path representing the solution to the maximization problem must satisfy the condition that marginal profit, at each point of time in which production occurs, will increase at the cartel's rate of discount r. Denote the marginal revenue obtained by the cartel at time t as MR_t. Since the extraction cost is assumed to be zero, the solution requires that

$$MR_t = MR_0\, e^{rt} \tag{4}$$

for all t in which $z_t > 0$.

In the extreme case when there is no synfuel capacity or production at any time, $y = 0$. Then the cartel faces the same demand curve in each period. Now we add the assumption that MR is a continuous, decreasing function of z (it must also be positive for some positive values of z). The requirement that MR increase at r means that z must decrease continuously over time, since the function $p(q) \equiv p(z+y)$ is continuous in z when $y = 0$.

Let $\tilde{T}$ represent the time at which exhaustion occurs on the optimal extraction path in the case of $y = 0$. Routine arguments show that $\tilde{T}$ is finite if there exists a choke price, that is, a price b such that $q(p) = 0$ for all $p > b$. Figure 1 (see Appendix) characterizes the price path under $y = 0$ when b is the choke price. When y is greater than zero, the nature of the solution depends on the relationship of $\tilde{T}$ to T, the time of the introduction of synfuels.

<u>Proposition 1</u>:

(a) If $T > \tilde{T}$, the level of synfuels production does not affect the extraction path of the cartel.

(b) If $T < \tilde{T}$, the presence of synfuels affects the cartel's extraction path, and for every initial exhaustible resource stock S_0 there exists a $\hat{y}$ such that:

(i) If the government chooses y less than $\hat{y}$, the cartel and synfuels producers will share the market from T until $T_x(y)$, the date of exhaustion of the conventional fuel. $MR(z_t)$ increases at the rate r during $[0,T_x)$. The fuel price rises continuously during $[0,T)$, takes a discrete drop at T, and rises continuously during $[T,T_x)$. The fuel price reaches $p(y)$ at time T_x, and remains at $p(y)$ thereafter. (See Figure 2 in Appendix.)

(ii) If the government chooses y greater than or equal to $\hat{y}$, conventional fuels will be exhausted at T. $MR(z_t)$ increases at the rate r during $[0,T)$. The fuel price rises continuously during $[0,T)$ and remains at $p(y)$ during $[T,\infty)$. If y is strictly greater than $\hat{y}$, the price falls at T. (See Figure 3 in Appendix.)

<u>Proof</u>:

The proof of part (a) is straightforward. Any positive y reduces demands and hence the profitability of production at each point in time after T, but has no direct effect on the period before T. If $T > \tilde{T}$, resource owners were not producing after T in the absence of synfuels; <u>a fortiori</u>, they will not do so if synfuels are produced. Thus there is no effect on the extraction path of $T > \tilde{T}$, independent of the level of synfuels.

The proof of part (b) requires more effort. The proof, provided in the Appendix, centers on the fact that the larger the value of y, the lower the demand for conventional fuels in the interval $[T,\infty)$, and the smaller the maximum marginal revenue obtainable by producing during that interval. From this it follows that there is a critical value $\hat{y}$ such that if y exceeds this value, the discounted marginal revenue from any path involving production during $[T,\infty)$ will always fall short of the discounted marginal revenue along the path which leads to exhaustion at T. Thus producers will prefer to exhaust by time T. Q.E.D.

<u>Proposition 2</u>:

Let T be less than $\tilde{T}$.

(a) If $y > \hat{y}$, $\frac{\partial z_t}{\partial y} = 0$

(b) If $y < \hat{y}$, $\frac{\partial z_t}{\partial y} \begin{cases} > 0 & 0 \leq t < T \\ < 0 & T \leq t < \infty \end{cases}$

Proof:

(a) If $y \geq \hat{y}$, the resource is exhausted at T. Since changes in y do not affect demands in $[0,T)$, then if z is the optimal path under $y = y_1 > \hat{y}$, it is also optimal under $y = y_1 + \delta > \hat{y}$.

(b) If $y < \hat{y}$, extraction continues beyond T. The value of any given resource stock remaining at time T declines continuously as y increases, by the assumption that marginal revenue is continuous and decreasing in q. Therefore, if y increases, it is in the cartel's interest to shift production from the period after T to the period before T. The requirement that marginal revenue must increase at the rate r within each period implies that when production is shifted from $[T,\infty)$ to $[0,T)$, it is reduced at every point in time in $[T,\infty)$ and increases at every point in time in $[0,T)$. Similar considerations apply for the case of a reduction in y. Q.E.D.

2. Competition Case

Similar propositions hold for the case of perfectly competitive resource owners who do, however, know what the price path will be. The competition case is a special case of the cartel case where marginal revenue is equal to price. As in the case of cartel ownership, market sharing will occur during a certain interval $[T,T_x)$ if T is less than $\tilde{T}$ and y is less than some critical value, $\hat{y}$. The one formal difference from the cartel case occurs when market sharing begins: under cartel ownership, a discrete drop in price occurs when synfuels join the market; under competition, no such drop takes place.[6] It should be noted that the values for $\hat{y}$, T_x, and $\tilde{T}$ are not the same in the cartel and competition cases.

In sum, in both the cartel and the competitive ownership cases, if the government introduces synfuels prior to $\tilde{T}$, it will influence the extraction path. If the level of synfuels production, y, is "small", market sharing will occur for a while. Higher values of y encourage the resource owners to extract more of the stock in the interval $[0,T)$. For suitably large values of y, resource owners will extract all of the stock prior to the introduction of synfuels. These summary remarks hold for both monopolistic and competitive ownership of the exhaustible resource, although the critical values will differ in the two cases.

B. The Government's Maximization Problem

The production of synfuels is assumed to involve a construction cost $x(y)$ incurred at time 0. We assume that $x(y)$ is continuously differentiable and that $x'(y) > 0$. To avoid unnecessary corner problems, we assume that $x(0) = 0$ and $x(\infty) = \infty$. Synfuels are produced at a constant marginal cost, c.

Define $u(q) \equiv \int_0^q p(\xi)d\xi$ as the gross social surplus in the importing country when q is the rate of consumption of the resource or its substitute. The usual caveats about the use of consumer surplus apply in this case.[7]

In this subsection we do not distinguish the cases of cartel ownership and competitive ownership of the exhaustible resource: the derivations are formally the same. Let V represent net social surplus. The government's objective is to:

$$(5) \qquad \max_y V = \int_0^\infty [u(q_t) - p(q_t)z_t]e^{-rt}\,dt - \int_T^\infty cye^{-rt}\,dt - x(y)$$

$$\text{where } q_t = \begin{cases} z_t, & 0 \leq t < T \\ z_t + y, & T \leq t < \infty \end{cases}$$

Thus the government seeks to maximize gross social surplus less the resource import cost and the cost of producing synfuels. Note that q_t depends on z_t, which will be chosen by the resource producers as a function of y. Substituting for q and differentiating with respect to y gives

$$\frac{\partial V}{\partial y} = \int_0^T [u'(z_t)\frac{\partial z_t}{\partial y} - p(z_t)\frac{\partial z_t}{\partial y} - z_t p'(z_t)\frac{\partial z_t}{\partial y}]\, e^{-rt}\, dt$$

$$(6) \qquad + \int_T^\infty [-p(z_t+y)\frac{\partial z_t}{\partial y} - z_t p'(z_t+y)\frac{\partial(z_t+y)}{\partial y}]\, e^{-rt}\, dt$$

$$+ \int_T^\infty [u'(z_t+y)\frac{\partial(z_t+y)}{\partial y}]\, e^{-rt}\, dt - \frac{c}{r} e^{-rT} - x'(y) = 0$$

It is instructive to examine the above expression in two cases:

Case 1: $y > \hat{y}$:

Recall that in this case, the extraction path leads to exhaustion at T, and $\frac{\partial z_t}{\partial y} = 0$. Here increases in synfuels capacity (beyond $\hat{y}$) have no effect on the price of conventional fuels, and thus there is no monopsony power benefit from additional synfuels production. This fact provides the basis for Proposition 3 below. The proof is given in the Appendix. The corollary relies on Proposition 1.

Proposition 3:

The optimal level of synfuels capacity is greater than $\hat{y}$ if and only if it is profitable for a competitive synfuels producer to expand capacity beyond $\hat{y}$.

Corollary:

If marginal construction costs are nondecreasing and synfuels are not privately profitable, then the optimal production of synfuels leads to market sharing with the exhaustible resource if synfuels are produced at all.

Case 2: $y < \hat{y}$

Using $u'(z_t) = p(z_t)$, the first integral in equation 7 reduces to

$$\alpha = \int_0^T -z_t p'(z_t) \frac{\partial z_t}{\partial y} e^{-rt} \, dt \tag{7}$$

This represents the change in consumer surplus in the interval $[0,T)$ occasioned by an incremental increase in y. Since $\frac{\partial z_t}{\partial y} > 0$ in $[0,T)$, α is positive; increases in y lower p in each instant in $[0,T)$, and raise consumer surplus.

The relationship $u'(z_t+y) = p(z_t+y)$ can be used to reduce the second and third integrals in equation 6 to

$$\beta + \int_T^\infty [u'(z_t+y)] \, e^{-rt} \, dt \tag{8}$$

where

$$\beta = \int_T^\infty [-z_t p'(z_t+y) \frac{\partial(z_t+y)}{\partial y}] \, e^{-rt} \, dt$$

The second term in expression 8 above is the marginal gross benefit from synfuels, equal to discounted unit revenue from synfuels production. The β term represents the change in consumer surplus in the interval $[T,\infty)$ from a change in y. This term will be positive if $\frac{\partial(z_t+y)}{\partial y} > 0$, or equivalently if $\frac{\partial z_t}{\partial y} > -1$, in $[T,\infty)$. But this is always true for $y < \hat{y}$. It is obviously true after T_x, since $z_t = 0$. If it were not true in $[T,T_x)$, then the marginal value of the resource would be the same (actually <u>higher</u> in the case of cartel ownership) after the increase in y as it was before. Since the marginal value has fallen in $[0,T)$ because of the additional production in that interval, this could not be optimal.

Thus, equation 6 can be rewritten as

$$\int_T^\infty u'(z_t+y) \, e^{-rt} \, dt + \alpha + \beta = \frac{c}{r} e^{-rT} + x'(y) \tag{9}$$

where the α and β terms represent the marginal benefits from synfuels production associated with monopsony power. Equation 9 indicates that a positive level of synfuels production may be desirable even if synfuels do not pay for themselves: at the margin, the discounted synfuels price can fall short of discounted construction costs and operating costs. The change in net social surplus from building a synthetic fuels plant has two components: the marginal profit or loss on the plant itself and the change in discounted consumer surplus from changing the extraction path of the resource and reducing the price paid for it. The second component is always positive (equal to $\alpha + \beta$), so a loss on the synfuel can be overcome by the gain due to the lowered price of oil. This is true whether the resource is owned by a cartel or competitive producers. These results are summarized in Proposition 4 below. Parts a and b follow directly from $\alpha + \beta > 0$ for $y < \hat{y}$.

Proposition 4:

(a) The optimal y may be greater than zero, even if synfuels production is not strictly profitable.

(b) If the optimal level of y is greater than zero but less than $\hat{y}$, the synfuels producer will lose money on production capacity at the margin.

In the analysis of this section, both resource producers and government operated with perfect knowledge and faced no uncertainty. Under special assumptions, uncertainty regarding the cost of synfuels could be incorporated without altering the analysis. Suppose the uncertainty regarding the costs took the following form:

$$x(y) = x + \varepsilon \quad c = c_e + \eta \quad E(\varepsilon) = E(\eta) = 0$$

with x_e and c_e certain, and with ε and η generated by white-noise processes. Under these circumstances, a government interested in maximizing the expected value of v would face the same problem as in equation (5), since the terms involving the errors disappear. The government would choose the same level of y as in the certainty case, provided $E(u(q_t)) = u(q_t)$.[8] The producers care only about y, so their decision would be unaffected.

3. The Cost of a Shut-Down Option

The model used in Section 2 assumed that the government credibly committed itself to operate the synfuels plant at capacity once it was completed. In this section, we explore the implications of relaxing that assumption. To highlight the issues, we first allow the government one additional decision: whether to shut down permanently before the plant comes on line.

We therefore assume that the government commits itself in two stages: at time 0 it commits itself to capacity y $(0 < y < \infty)$; then at time T it commits itself to a level of operation, either zero or y. We assume that the exhaustible resource producers are informed about the nature of government's decision process and will believe the commitments at each stage. We thus have the following sequential game:

t=0: The government commits to a capacity level y, based on S_0, costs, and anticipated responses of resource producers.

Resource producers respond to y, taking into account the effects of their response on the government's subsequent decisions at time T.

t=T: The government decides whether to operate or shut down, based on S_T, operating costs, and the anticipated responses of resource producers.

Resource producers determine their extraction path, based on the government's decision whether to operate.

At time T, the extraction path of the producers from 0 to T is given and the construction costs of the synfuel plant paid. The government will operate if the present value from operation relative to shutdown is positive. From equation (5), it will operate if:

$$(10) \qquad \int_T^{\infty} [(u(z_t^*+y) - u(z_t)) + (p(z_t)z_t - p(z_t^*+y)z_t^*) - c_y]e^{-rt}\, dt > 0$$

where z_t^* is the extraction path chosen if the government operates the plant and z_t is the path chosen if the government shuts down.

Whether the government decides to shut down at time T will depend on S_T, the stock of the resource remaining at that time. Although the gross social benefit attributable to synfuels production is monotonically (negatively) related to S_T, the overall benefit from synfuels may increase or decrease. A higher value of S_T implies higher values of both z_t and z_t^*. This implies that the gross social benefit from synfuels, represented by the term

$$u(z_t^* + y) - u(z_t)$$

in equation (10), will fall as S_T rises. The term

$$p(z_t)z_t - p(z_t^* + y)z_t^*$$

also depends on S_T, and reflects the gain from paying lower prices for oil as a result of synfuel production; this may decrease or increase as S_T increases. The possibility that the second term increases with S_T makes condition (1) in the proposition below necessary.

Having the option to shut down can affect the value for S_T that results in the two-stage game, and thus the option itself influences whether shutdown will in fact occur. The option to shut down will typically harm the government when there is no uncertainty, whether it is facing a cartel or competitive producers. This result[9] stems from the strategic influence the shutdown option gives to producers in the cartel case and from the changed equilibrium possibilities in the competition case. Producers can ignore (or, in the cartel case, do worse than ignore) the synfuel plant. Under some conditions, ignoring the synfuel plant before T will cause the government to shut down the plant. In those circumstances, a dynamically consistent path of decisions results under which the government incurs the construction cost to no purpose.

The result will be proven first for the cartel, then for competitive producers.

<u>Proposition 5</u>:

In a world of perfect certainty, the importing nation facing a cartel is never better off and may be worse off if the government has the option to shut down permanently at time T rather than produce at capacity, providing:

(1) higher levels of the resource stock remaining at time T reduce the gain to the government from producing compared with shutting down, and

(2) the extraction rate in the absence of synfuels is not faster than the optimum for the importing country.

<u>Proof</u>:

Let $\hat{S}_T$ be the value of the resource stock which makes the government indifferent between producing and shutting down. By condition (1), the government will shut down if $S_T > \hat{S}_T$ and will produce at capacity if $S_T < \hat{S}_T$.

Define Z_m as the optimal extraction path for the monopolist producer who knows with certainty that synfuels will not appear on the market under any circumstances. Define $S_T(Z_m)$ as the resource stock remaining at time T under path Z_m. Consider two cases:

Case 1: $S_T(Z_m) > \hat{S}_T$

In this case, pursuing the extraction path that would be optimal if synfuels technology did not exist causes the government to shut down, that is, prevents synfuels from being produced. The profits enjoyed by the cartel when it chooses the path Z_m are the same as the profits it would earn if synfuels technology did not exist, since synfuels do not appear on the market under Z_m. By the definition of Z_m, these profits must be at least as great as those provided by any other path which induces the government to shut down. Since any extraction path, given the appearance of synfuels, yields lower profits than the optimal path given the absence of synfuels technology, the cartel will prefer Z_m over any path which does not lead the government to shut down. Thus Z_m will be chosen by the cartel.

Case 2: $S_T(Z_m) < \hat{S}_T$

Define Z_o as the extraction path which is optimal for the monopolist producer when the government commits itself to both construction and operation at some level y. Define $S_T(Z_o)$ as the resource stock remaining at time T under path Z_o. Since $\frac{\partial z_t}{\partial y} > 0$ for all t in $[0,T)$, $S_T(Z_o) < S_T(Z_m)$. Therefore $S_T(Z_o) < \hat{S}_T$. Therefore the extraction path Z_o, if undertaken when the government has the shutdown option, leads the government to operate the plants. Note that any given extraction path Z which leads the government to choose to operate the synfuels plants generates the same revenue as it would if the government had a prior commitment to generating the plants. Therefore path Z_o must be preferred by the cartel to any other which leads the government to operate. The government does not exercise the shutdown option and is indifferent to having it. However, there is another option for the cartel. It can produce even more slowly in $[0,T)$ and have a large stock $\hat{S}_T$ remaining. This will cause the government to shut down. Under most circumstances, a monopolist in the absence of synfuels is already producing too slowly.[10] This outcome is therefore disastrous for the government, since it has pushed the cartel the wrong way and is out the construction cost besides.

Q.E.D.

Proposition 6:

In a world of perfect certainty, the importing nation facing competitive producers is never better off and may be worse off if the government has the option to shut down permanently at time T rather than produce at capacity, providing:

(1) higher levels of the resource stock remaining at time T reduce the gain to the government from producing compared with shutting down.

Proof:

When the producers are competitive, a different set of circumstances yields a similar type of result. Here the producers cannot collude, and there are only two potential stable equilibria: the producers following the extraction path, Z_c, that would have resulted in the absence of synfuels, with the stock remaining, $S_T(Z_c)$, being large enough to cause a shutdown; or their following the extraction path, Z_o, that would have occurred if production were certain, with the remaining stock, $S_T(Z_o)$, being too small to discourage the government from producing. Since $S_T(Z_o) < S_T(Z_c)$, if $S_T(Z_c) < \hat{S}_T$, the Z_o path will be the only equilibrium; the government will produce and will be indifferent to having the shutdown option. If $S_T(Z_o) > \hat{S}_T$, the Z_c path will be the only equilibrium; the government will shut down and it will regret its construction expenses. The most interesting situation arises when $S_T(Z_o) < \hat{S}_T < S_T(Z_c)$. In this case both the equilibrium with $S_T(Z_o)$ and the one with $S_T(Z_c)$ are stable, and the latter equilibrium entails higher profits. Yet the equilibrium with higher profits will not necessarily emerge. No dominant strategy equilibrium exists. The government may be worse off, and will be no better off with the shutdown option. Q.E.D.

As in the cartel case, in the competition case producers strategically influence the government's decision whether to operate. Even though no individual competitive producer can influence or expect to influence government behavior, the effective result of competitive behavior — and in particular, arbitrage activity -- exerts a strategic effect. The arbitrage activity expresses individual expectations about the future potential of synfuels to enter the market, ensures that no unexpected opportunities for profit remain in equilibrium, and generates production paths which affect the government's decision whether to operate.

The analysis is more complex if the gain to the government from producing rather than shutting down is <u>not</u> a decreasing function of S_T. In the cartel case, there may be a gain to the importing country from the shutdown option. If the option causes the cartel to <u>reduce</u> S_T in order to induce shutdown, the nation may gain sufficient consumer surplus to offset the lost construction costs. In the competitive case, no pure strategy equilibria may exist. This would occur if Z_c led to synfuel production and Z_o to shutdown. Whatever the extraction path, some producers are going to regret their decisions. However, if Z_m (for the cartel) or Z_c (for the competitive producers) would lead to shutdown, that path is an equilibrium and the government will lose by having the option.

It is very likely, therefore, that the government will be better off without the opportunity to change its mind. This result reflects dynamic inconsistencies in the outcome of the game between the government and the producers. When $\hat{S}_T < S_T(Z_o)$, in either the cartel or competitive case, the government's decision is dynamically inconsistent in the local sense used by Kydland and Prescott (1977), since the government will not want to operate even if producers believe it will.

The above analysis indicates that, in addition, there may be a problem of global dynamic consistency. When $S_T(Z_o) < \hat{S}_T < S_T(Z_m)$ in the cartel case or $S_T(Z_o) < \hat{S}_T < S_T(Z_c)$ in the competition case, there exists an outcome — the Z_o extraction path -- which is locally dynamically consistent.[11] The government's announcement is consistent with its later decision, as is the extraction path chosen by the producers. However, there also exists an equilibrium which is dynamically inconsistent, since it will not be in the government's interest to abide by its announcement.

However, when $\hat{S}_T$ is large enough, no dynamic consistency problem -- local or global -- arises. In such circumstances, the synfuels program escapes the sort of inconsistency problem associated with optimal tariff policies (see Maskin and Newbery (1978)).[12,13]

4. The Cost of a "Mothballing" Option

Will having the milder option of mothballing the synfuel plant benefit the government? The answer is no, under conditions similar to Propositions 5 and 6, so long as the original time the plant was to come online was optimally chosen. The intuition is the same as above. Any change in the production path caused by the lack of commitment is bad news for the importing country.

The mothballing option is modelled by allowing the government to select at time 0 the capacity level y and earliest opening date T for the synfuel plant. At some predetermined time $\tau < T$, the government selects a time T', with $T < T' < \infty$, at which the plant will begin operation. Once the plant begins operation, it must be operated at capacity forever. Construction and operating costs for the plant are assumed to be at least as large for T' as for the case where the government chooses the opening date at the initial stage. The exhaustible resource producers are informed about the nature of the government's decision process and believe the commitments at each stage. We are therefore considering the following sequential game:

$t = 0$: The government commits to a capacity level y and an earliest starting date T, based on S_0, construction and operating costs, and the anticipated response of resource producers. Resource producers respond, taking into account the effects of their response on the government's subsequent decision at time τ.

$t = \tau$: The government chooses the time T' to begin operating the plant, based on costs, S_τ, and the anticipated responses of producers. Resource producers determine their extraction path based on the government's decision when to operate.

Let y^* and T^* be the optimal values of y and T for the government in the single stage game, where the government does not have a mothballing option. Note that this single-stage game is different from the model in Section 2, since the government can choose the starting date, T. Proposition 7 states conditions under which the mothballing option can never help the government.

Proposition 7:

In a world of perfect certainty, the importing nation is never better off, and may be worse off, if the government has the option to postpone production rather than commit to y^* and T^* in the single stage game, providing:

(1) in the competitive case, a Nash equilibrium exists for the resource producers in the two-stage game.

(2) in the cartel case, T' is an increasing function of S_τ and the extraction rate for any T in the single-stage game is not faster than optimal from the importing nation's perspective.

Proof:

The proof for the competitive case is straightforward. The only possible equilibrium paths for the producers, in the absence of uncertainty, are those which are consistent with the T' chosen by the government if the producers follow that path. The government could have achieved those extraction paths by selecting the corresponding T' in the single-stage game. Such a choice in the single-stage game would be at least as good as the outcome of the two-stage game, since, by assumption, construction and operating costs without the option are no larger. Therefore, the government is no better off with the option, since T^* was optimal in the single-stage game.

Postponement of the starting date is always better for the cartel. Since larger S_τ will postpone production by assumption, the cartel will choose at least as large an S_τ in the two-stage game as it would for the same T' in the single-stage game. Since the cartel was not producing too quickly in the single-stage game, the government is no better off than in the single-stage game which results in T'. Since T^* was the optimal choice for the government in the single-stage game, and since costs are at least as high for any choice of T' in the two-stage game as in the one-stage game, the government is no better off in this case.

Q.E.D.

The addition of uncertainty regarding operating costs would create additional possibilities for the government to gain from a shut-down option.

Construction cost uncertainty, in a model where the government cannot shut down until the plant is completed, would not change Propositions 5 or 6 substantially. With an option, however, the government can stop the synfuels project if the operating costs get too high. This benefit must be weighed against the disadvantages of flexibility; the tradeoff clearly depends on the variance of operating costs. Producers, if the government had an option, would be uncertain about whether shutdown would occur. In the competitive case, a level of production intermediate between Z_c and Z_o would be chosen.

5. Conclusion

In this paper we have examined government intervention in the production of synthetic fuels for a nation with potential monopsony power in the market for conventional exhaustible resources. The consequences of synfuels production were analyzed in the framework of a Stackelberg game involving the government of the synfuels producing nation and owners of the exhaustible resource; the government was the Stackelberg leader.

We find that the decision by owners of the exhaustible resource whether to share the market with synfuels or to exhaust the resource prior to the introduction of synfuels depends on the quantity of synfuels produced. In particular, there exists a critical quantity of synfuels $\hat{y}$ such that resource owners will share the market with synfuels if and only if the actual level of synfuels production is less than $\hat{y}$. These results hold in the case of monopolistic ownership of the exhaustible resource and the case of competitive ownership, although the critical quantity will differ in the two cases.

The optimal level of synfuels production, from the point of view of the synfuels producing nation, is analyzed formally in terms of the monopsony power benefits and other benefits associated with production of these fuels.

We find that if marginal construction costs are non-decreasing, the optimal synfuels quantity will be greater than $\hat{y}$ -- and therefore will result in the conventional resource being exhausted prior to the introduction of synfuels -- only if synfuels production is privately profitable.

A two-stage game is developed in order to analyze alternative types of committment to synfuels by the government. In the absence of uncertainty, a prior commitment to build and operate synfuels plants is shown to be preferable in general to a commitment simply to build which leaves the government with the option to shut down or mothball the synfuels plants after their construction. When the government reserves the option to shut down, it thereby grants exhaustible resource owners additional strategic influence which can result in their embarking on a very conservative extraction path in order to induce the government to shut down; this will generally have adverse consequences for the importing nation. Very similar results occur when the government has the option to postpone the operation of the synfuels plant.

Although these results indicate that additional flexibility regarding the operation of the synfuel plant is often detrimental to the importing country, it should be kept in mind that the analysis assumes a world of certainty. In reality, the benefits of inflexibility in terms of eliminating certain kinds of strategic behavior must be weighed against the costs of being unable to respond to new and better information. The current analysis should serve as a basis for developing a framework in which uncertainties regarding construction and operating costs, demands, reasonable stocks and required lead times are considered.

Footnotes

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[1]The literature on optimal tariffs may apply not only to the oil market but also to other commodity markets in which the domestic country enjoys monopsony power. For a general discussion of optimal tariff issues, see Bhagwati (1969) and Dixit and Norman (1980). For a discussion of these issues as applied to U.S. imports of oil, see Folkerts-Landau (1984) and Mork (1982).

[2]We consider alternative assumptions in the next section.

[3]We ignore the effect of synfuels production on the demand for the exhaustible resource, either directly or through the energy opportunity cost of the resources used (see Baumol and Wolff (1981) for an excellent discussion of this issue). Our later conclusion that optimal synfuels production may be unprofitable at the margin would survive with this modification, since prices are affected by synfuels production in our model, unlike that used by Baumol and Wolff.

[4]In reality, the demand for fuels will depend somewhat on expected future prices of fuels. These expectations may influence current investments in fuel-burning equipment (as opposed to equipment which relies on coal or nuclear-generated electricity) and thereby affect fuel demands once the equipment goes online. In this paper we concentrate on issues related to lead times in the production of fuel-<u>supplying</u> equipment (e.g., a synfuels plant); however, as the discussion here indicates, additional issues are raised by

lead times in the production of fuel-<u>using</u> equipment.

[5]One could redefine price and costs so that the analysis would be formally identical for constant extraction costs. Increasing extraction costs, however, would complicate the analysis.

[6]The demand for conventional fuels shifts inward at T, the time when synfuels are introduced. Under both cartel ownership and competitive ownership, optimality requires that marginal revenue be the same just before and after T. As discussed in the proof of part b of Proposition 1, a discrete drop in price is necessary to insure the marginal revenue condition under cartel ownership. Under competitive ownership, marginal revenue is equal to price, and thus the price does not drop at time T.

[7]The analysis is largely unchanged if some externality, such as a national security premium, is included in the welfare function. We avoid this complication.

[8]If η and ε were large enough that the concavity of the utility function could not be ignored, this condition would not be satisfied.

[9]The advantages of being able to commit to an action have been stressed in other contexts by many authors. See, for example, Kydland and Prescott (1977), Stiglitz and Weiss (1981), Bulow (1982) and Nellor and Robinson (1983).

[10]See Stiglitz (1975) and Weinstein and Zeckhauser (1975). The possibility that the cartel extracts too rapidly leads to condition (2) of the theorem. Even if condition (2) were not satisfied, it is unlikely the government would be better off with an option to shut down.

[11]Even if $\hat{S}_T > S_T(Z_m)$, a global inconsistency problem may arise, as discussed in the above proof. Note also that the Z_o extraction path is different in the cartel and competitive cases.

[12]We do not advance this point as an argument that subsidies will generally be superior to tariffs as a means of exercising monopsony power in exhaustible resource markets. However, it is meant to provide a rationale for giving subsidies serious consideration as alternatives to tariffs. Subsidies are generally thought to create distortions by lowering prices to consumers below the optimum, and tariffs do not have this drawback. But the practical difficulties of implementing the optimal tariff -- arising in part from dynamic inconsistency -- make subsidies deserve attention. It may be noted that the best feasible policy might involve both a tariff and a subsidy: under some circumstances, the optimal tariff's dynamic inconsistency problem can be tamed through binding contracts (subsidies) between the government and domestic producers of the substitute fuel. These contracts eliminate the incentive for the government to renege on its tariff pledges.

[13]The proofs in this section hold even if $S_T(Z_o) = 0$ -- that is, the resource is exhausted.

Appendix

Proof of Proposition 1, Part b.

The profit-maximizing extraction path requires that discounted marginal profit (or marginal revenue, since marginal costs are zero), $MR_t(z_t)e^{-rt}$, be constant for all t in which $z_t > 0$. Consider the optimal solution to the monopolist's problem under the constraint that exhaustion must occur at time T. Call the value of discounted marginal revenue for this solution MR_0^*. It will be nonnegative if there is free disposal of the resource; its value is a function of the initial stock S_0, the shape of the demand curve, and T.

Now consider the circumstances under which the cartel would prefer to extend production beyond T. Suppose that $MR_{T+\varepsilon}(0)\ e^{-r(T+\varepsilon)} < MR_0^*$, that is, the discounted marginal revenue, after synfuels are introduced, of the first unit of production is less than MR_0^*. Since, by assumption, MR decreases with z at any point in time, $MR_{T+\varepsilon}(0)$ is the highest marginal revenue obtainable at time $T + \varepsilon$. Further, since demands are identical at all points of time in $[T,\infty)$, then for all $t > T+\varepsilon$,

$$MR_{T+\varepsilon}(0)\ e^{-r(T+\varepsilon)} > MR_t(0)\ e^{-rt} > MR_t(z_t)\ e^{-rt}$$

for all $z_t > 0$. Therefore if $MR_{T+\varepsilon}(0)\ e^{-r(T+\varepsilon)} < MR_0^*$, the discounted marginal revenue for the first unit or any successive unit of extraction at time $T+\varepsilon$ or afterward, will fall short of MR_0^*. This implies that shifting any production from $[0,T)$ into $[T,\infty)$ will lower discounted profits. Therefore the cartel will never wish to share the market with the synfuels producer if $MR_{T+\varepsilon}(0)$
$e^{-r(T+\varepsilon)} < MR_0^*$. Thus, if the government wishes to assure no market sharing, it can do so by choosing $y = \hat{y}$, where

(A1) $$\hat{y} = q(MR_0^* e^{rT})$$

This shifts the residual demand curve faced by the cartel inward in such a way that $MR_{t+\varepsilon}(0)\ e^{-r(T+\varepsilon)} < MR_0^*$, making production of the resource in $[T,\infty)$ disadvantageous. (See Figure 4.)

Clearly if $y > \hat{y}$, $MR_{T+\varepsilon}(0)^{-r(T+\varepsilon)}$ will be even lower, and resource extraction beyond T will not be optimal. On the other hand, if $y < \hat{y}$, $MR_{T+\varepsilon}(0)\ e^{-r(T+\varepsilon)} > MR_0^*$, and the deferral of at least one unit of extraction beyond T increases profits. Thus $\hat{y}$ is a critical value for y: if $y < \hat{y}$, the cartel will prefer to exhaust after T; if $y > \hat{y}$, the cartel will prefer to exhaust at T.

The characteristics of the price paths in the cases $y < \hat{y}$ and $y > \hat{y}$ remain to be shown. Optimality requires that marginal revenue (MR) increase continuously. In the interval $[0,T)$, output z is continuous and decreasing in MR (since, by assumption, MR is continuously decreasing in z). Price is also continuous and decreasing in z since during this interval the monopolist faces the continuous inverse demand function, $p(z)$. Thus the optimum implies that the resource price rises continuously in $[0,T)$. Similar considerations show that if production occurs beyond T (that is, if $y < \hat{y}$), the resource price rises continuously in $[T,T_x)$.

If $y < \hat{y}$, some of the resource is produced after T. Marginal revenue to the cartel must be the same just before and after the plant comes on line. Since there has been a horizontal leftward shift in demand at T, this is only possible if the price drops discretely at T (at any given price, marginal revenue is greater after the shift than before). The intuition is that the cartel does not care about the effect of its output decision on the profits to the synfuel producer.

If $y > \hat{y}$, the conventional resource is exhausted at T. By the definition of $\hat{y}$, $p(\hat{y})$ is equal to the marginal revenue of the resource just before T when the cartel pursues the optimal path leading to exhaustion at T. Since marginal revenue is less than price, $p(\hat{y})$ is less than the cartel's price just before T. Since the conventional resource is not produced during $[T,\infty)$, $p(y)$ is the market price from T on. The larger is y, the smaller is $p(y)$ compared with $p(\hat{y})$, and the larger is the price drop at time T.

Proof of Proposition 3

If $y > \hat{y}$, the first integral in equation (7) reduces to 0. Using the fact that $\frac{\partial z_t}{\partial y} = 0$ and $z_t = 0$ in $[T,\infty)$, the second integral drops out and we can write the third integral as $\frac{1}{r} u'(y)e^{-rt}$. The entire expression therefore becomes

(A2) $$\frac{1}{r} e^{-rT} (u'(y)-c) - x'(y) = 0$$

Note that $$v''(y) = \frac{1}{r} e^{-rt} u''(y) - x''(y).$$

If marginal construction costs are constant or increasing in y, $V''(y)$ will be negative. Under these circumstances, if $V'(\hat{y}) < 0$, then any increase in y beyond $\hat{y}$ reduces social welfare. Expansion of capacity beyond $\hat{y}$ can only be justified if $v'(\hat{y}) > 0$, that is, if

(A3) $$\frac{1}{r} e^{-rT} (u'(\hat{y}) - c) > x'(\hat{y}).$$

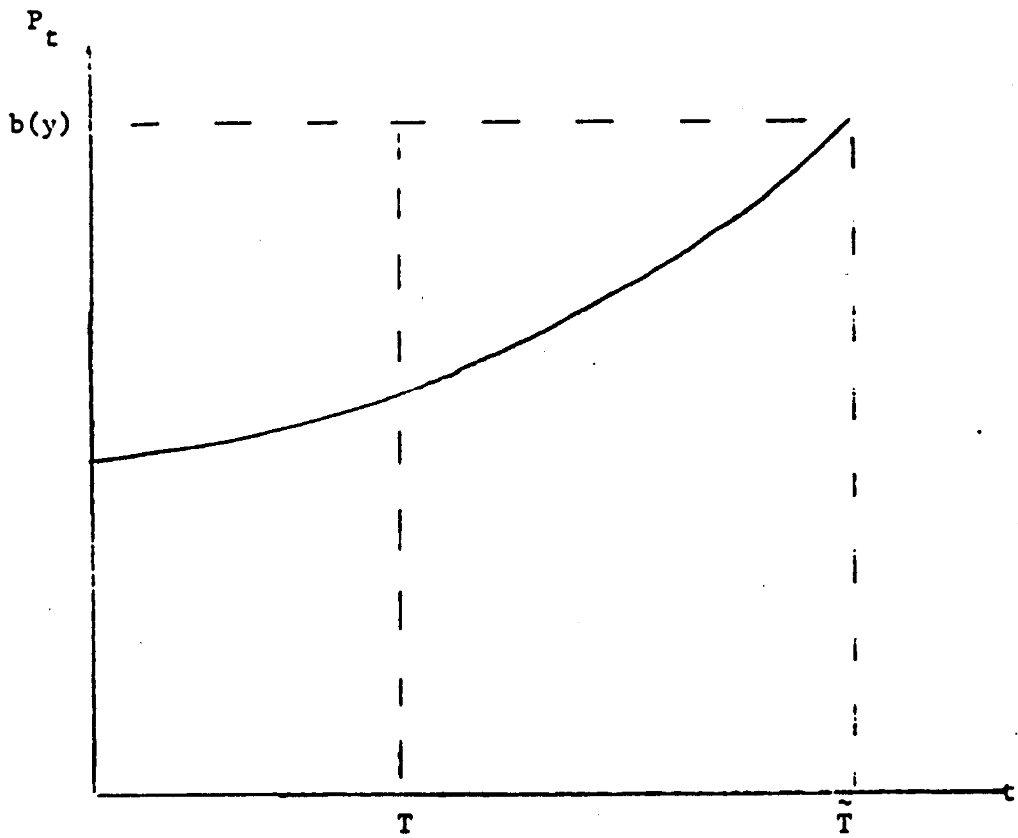
The discounted stream of marginal net benefits from synfuels must exceed the marginal construction costs. If $u' = p$, this is exactly the condition for a price-taking synfuels producer to expand capacity beyond $\hat{y}$. If condition (A3) holds, a maximum exists for some $y > \hat{y}$ where $\frac{1}{r} e^{rT} u'(y) =$

$x'(y) + \frac{1}{r} e^{-rT} c.$

It should be noted that the optimality condition in equation (A2) above is independent of both the price and quantity of the exhaustible resource. Since increases in y beyond $\hat{y}$ have no effect on the resource's extraction or its price path, these strategic considerations do not enter into the calculation of the marginal benefits and costs of increasing y beyond $\hat{y}$. Synfuels capacity should be expanded beyond $\hat{y}$ only if the additional output pays for itself.

Figure 1

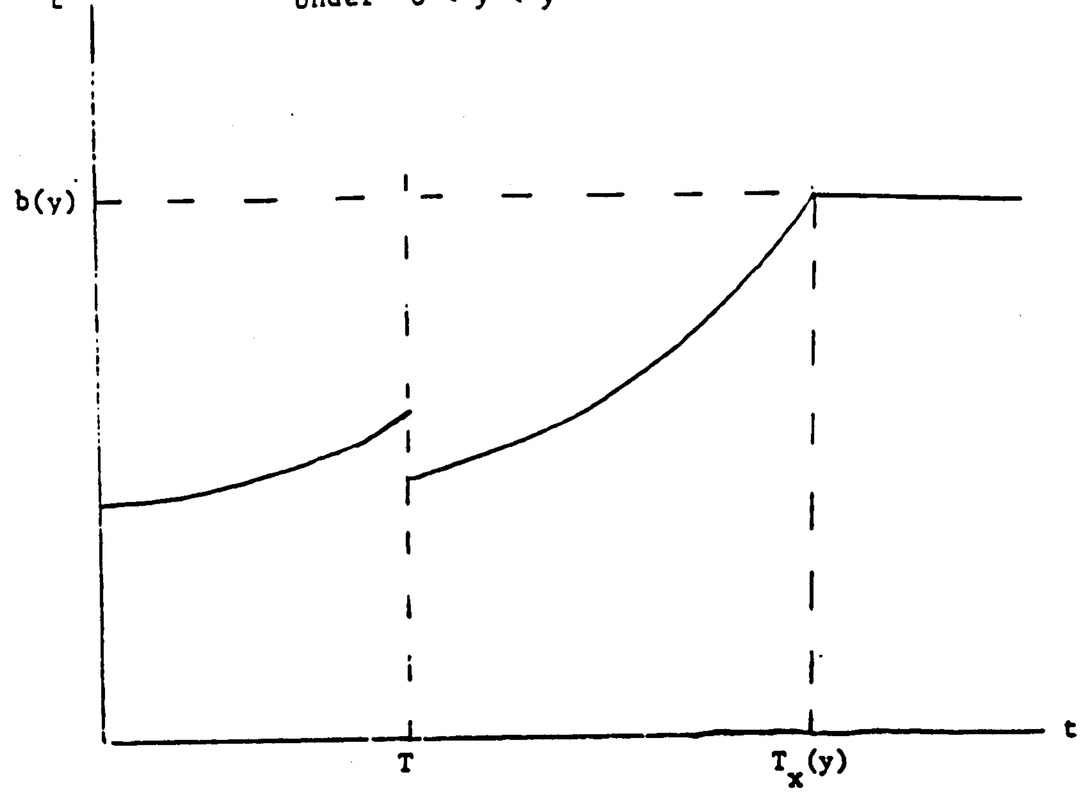
Price Path in Cartel Ownership Case
Under $y = 0$



($MR_t = MR_0 e^{rt}$ during $[0, \tilde{T})$.)

Figure 2

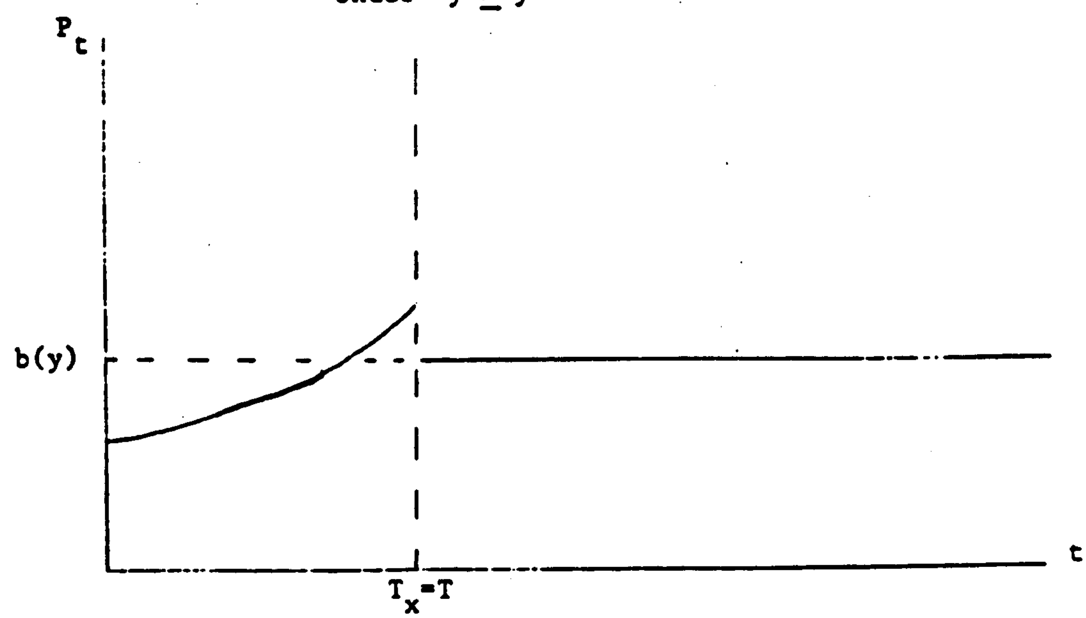
Price Path in Cartel Ownership Case
Under $0 < y < \hat{y}$



($MR_t = MR_0 e^{rt}$ during [0, T) and during [T, T_x). Conventional fuel and synfuels share market during [T, T_x). $\partial z_t/\partial y > 0$ in [0, T); $\partial z_t/\partial y < 0$ in [T, ∞).)

Figure 3

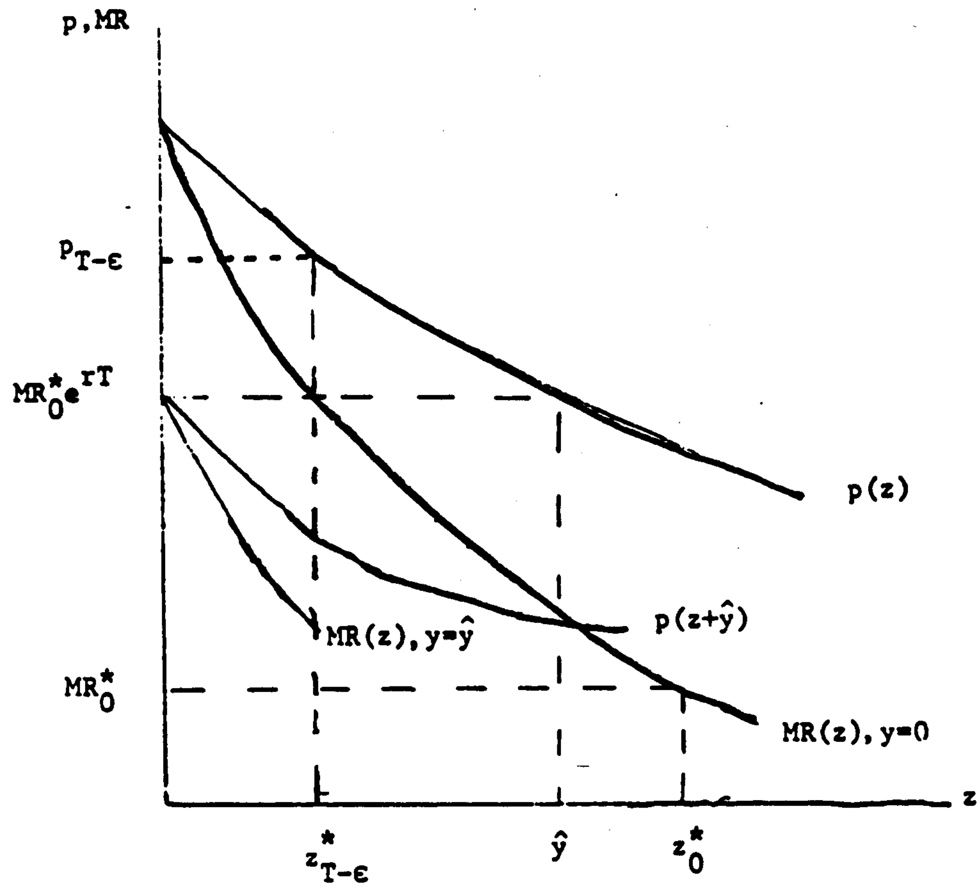
Price Path in Cartel Ownership Case
Under $y \geq \hat{y}$



($MR_t = MR_0 e^{rt}$ during 0, T). No market sharing. $\frac{\partial z_t}{\partial y} = 0$.)

Figure 4

Relationship Between Conventional Fuel Demand and $\hat{y}$, Cartel Ownership Case



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