

**WHY WORLD OIL MONOPOLIZATION LOWERS OIL PRICES:  
A THEORY OF INVOLUNTARY CARTELIZATION**

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**INTRODUCTION**

A major peculiarity of modern economic history has been the systematic nature of the glut-induced declines in world oil prices that have accompanied the monopolizations of the world's crude oil market, together with the analogous jumps in world oil prices that have immediately followed the subsequent de-monopolizations of that market. The supply-induced fall in real crude oil prices accompanying the emergence of the Standard Oil Trust in the 1870s and 1880s, the jump in crude oil prices that immediately followed the sudden 1911 break-up of the Standard Oil Trust, the supply-induced declines in real crude oil prices accompanying the fitful emergence of the U.S.-led "Seven Sisters" from the mid-1920s through the late 1960s, the sudden declines in output and corresponding jumps in world oil prices that came with the monopoly-breaking Middle-Eastern nationalizations during the 1970s, and the steady increases in oil production are gradual

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\* Adnan Mazarei, currently at the IMF, provided much more than a research assistant's contribution to the empirical content of this paper. But for writing down a detailed historical-institutional elaboration of the following argument, which would surely increase the general credibility of the argument, he would be a co-author of this paper. On the other hand, as the facts employed in this paper are all stylized in order to facilitate the development of the sometimes-delicate theoretical argument, some points of historical-institutional disagreements between us may remain. In any case, the author is solely responsible for whatever errors may appear in this paper.

decreases in real oil prices since the early 1980s as the U.S. has gradually come to re-assert its political hegemony over the world's oil-producing regions -- all of the major movements in the history of oil production and prices -- amount to the same empirical contradiction of conventional economic thought.

The oil industry has been viewed both statically, as a perishable-goods industry subject to a standard comparison of competitive with monopolistic pricing practices (e.g., Adelman, Houthakker, and many others), and dynamically, as an industry arising to temporarily exploit an exhaustible natural resource by selecting alternative, present-value-maximizing, rates of competitive or monopolistic resource exploitation (e.g., Hotelling, Stiglitz, and many others). But neither view has prepared us for the above empirical paradox.

Economic discussions of the history of oil prices have been correspondingly awkward. We thus read of the "great oil discoveries" of the 1870s and 1880s, and again of the 1930s-1960s, windfall discoveries that made crude oil prices fall despite the coincident monopolization; but we seldom see any explanation of the increases in oil exploration that accompanied the historic monopolizations. And we commonly read, after the 1973 and 1979 price jumps, of the sudden formation of a "monopolistic oil cartel" even though: (1) the pre-1973, U.S.-supported oil consortia had far more monopoly ownership and control over world oil production than any single country or organization had after the 1970s nationalizations of U.S. oil interests; and (2) OPEC has eschewed all of the obvious devices for inducing a collective reduction in total cartel output in favor of

customer-monitored price and quantity controls.<sup>1</sup>

Now economists have long been aware, at least since the pioneering work of Schelling on bilateral monopoly and Coase on durable-goods monopoly, that monopolists generally face a "time-inconsistency", i.e., a future-optimal pricing plan that contradicts their presently optimal pricing over the same span of future time. But only rarely do we find economic discussions in which such time-inconsistencies are resolved in order to

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<sup>1</sup>This absence of anything resembling an optimally monopolistic cartel policy has induced many critical oil observers to dismiss the common view that OPEC is analyzable as a monopolistic cartel. However, thoroughly non-monopolistic views have uniformly characterized these critical observers. In particular, these minority views emphasize changes in property rights and capital market imperfections within a steadily competitive market environment in their attempts to explain the OPEC price hikes of the 1970s.

Johany (1980), for example, argues that the switch of ownership from the relatively insecure, therefore short-horizon, U.S. oil-companies to the relatively secure OPEC countries in the early 1970s lowered the discount rate of the relevant decision-makers and thereby lowered the production rates of the OPEC countries. Even if this view were a qualitatively accurate characterization of the relevant horizons of the alternative oil-owners (which it almost certainly is not), the view is not consistent with the price-increasing effect of the 1979 shock, which clearly increased the insecurity of existing owners.

Another, more recent, strand in the literature on market imperfections suggests that OPEC members, rather than forming a monopolistic cartel, individually follow a target-revenue policy. Each country separately determines its development budget and proceeds to produce only that amount of oil satisfying these budgetary needs. Oil revenues above and beyond these budgetary needs are not pursued because of the limited "absorptive capacity" of these economies and imperfections in international capital markets (e.g., Teece (1982)). As a result, OPEC countries display a backward bending supply curve for oil, and the observed reductions in output that have accompanied the price increases are the result of normal, imperfectly competitive, supply responses to the demand increases of the early 1970s (Cremer and Salehi-Isfahani (1991)). Besides similarly failing to explain the second jump, 1979, in oil prices, and the steadily mounting fiscal deficits of OPEC's dominant members, the hypothesized capital-market imperfection is wholly inconsistent with the fact that the superior security of a balanced portfolio of diversified foreign assets relative to a portfolio of domestically fixed assets increases with the price of the latter assets.

Section II below will deal with the nature and consequences of OPEC-type cartelization.

inform us as to how actual decisionmakers behave.<sup>2</sup>

We submit that the above-described peculiarities, paradoxes, and inconsistencies can all be eliminated by a simple resolution of a fundamental time-inconsistency facing any monopolistic owner of an exhaustible natural resource.

## I. RESOLVING PARADOXES

### A. The Fundamental Time-Inconsistency

The particular time-inconsistency characterizing a crude-oil monopoly is quite obvious. At any point in time, a crude-oil monopolist has already sold a significant quantity of as-yet unconsumed oil. An increase in the monopolist's current rate of output, and correspondingly increase in the current period's rate of oil consumption, will therefore both lower the value of these previously sold reserves and raise the value of the monopolist's unexploited reserve, thereby redistributing wealth toward the monopoly and away from its previous purchasers. Besides representing a time-inconsistent redistribution, this effect implies a monopolistic misincentive.

Like any monopolistic inefficiency, the misincentive arises because the monopolist internalizes a self-redistributive, or "pecuniary", effect that competition would leave external. In the case of a crude-oil monopolist, however, the pecuniary benefit, the

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<sup>2</sup>Rather, theoretical niceties such as time-inconsistency are typically -- quite indefensibly -- regarded by economists as being too difficult for sub-Oddysean decisionmakers -- especially governmental decisionmakers -- who are implicitly presumed too weak-minded or unsophisticated to attack such subtle problems. In contrast to this standard view, the author (e.g., 1974, 1979, 1980a,b, 1981) has argued that individual decisionmakers -- especially governmental decisionmakers -- not only respond to such time-inconsistencies -- but optimally solve wide classes of such policy problems long before economists and other social thinkers even conceive of them. An extended example of this latter argument, one particularly relevant to OPEC-type cartelization, will be provided in Section II below.

induced increase the value of the inframarginal output, comes from expanding the current period's rate of production. In particular, expanding production at the end of a current production cycle increases the value of the monopolist's inframarginal -- i.e., future -- oil reserves, an effect that a competitive crude-oil supplier would simply ignore. While such an increase in production has a largely offsetting current price-effect because the rationally anticipated increased production also lowers the price of pre-existing oil supplies, the corresponding pecuniary loss is external to an end-of-period monopolist. This is because the pre-existing stock of currently consumable crude oil has already been sold when the relevant production decision is made.

If the oil monopolist had subjected all of the current-period's oil production decisions to a pre-set price or quantity commitment -- an assumption that is completely unrealistic in the traditionally observed institutional environment but is nevertheless implicit in the standard dynamical literature on natural-resource monopolies -- the above-described current price and redistributive effects would have been internalized by the monopolist when pre-committing to the current production rate. In such a case, as we have already indicated, no systematic under- or over-production effect would emerge (e.g., Stiglitz, and Lewis, Matthews, and Burness).

Why, then, would we ever observe the formation of a world crude-oil monopoly? A competitive solution (which again approximates the costly, pre-commitment, monopoly solution) is more profitable to the oil producers than the uncommitted monopoly solution. Indeed, other such wasting natural resources (e.g., coal and various metallic ores) are seldom the subject of monopolistic cartels.

## B. Why Crude-Oil Sellers Monopolize

The answer, at least at the private level, is that current buyers of crude oil -- in particular oil refiners -- own significant amounts of a replaceable, depreciating, physical asset whose economic value is substantially enhanced by lower current crude-oil prices.<sup>3</sup> These large buyers, by vertically integrating into crude-oil production and reserve-acquisition, create for themselves an opportunity to organize a world crude-oil monopoly, an institution that will substantially lower the prices of crude-oil inputs complementing their physically depreciating capital stocks. Indeed, history's two major crude-oil monopolizations -- the formation of the Standard Oil Trust and of the "Seven Sisters" -- were cartelizations of oil refiners gaining substantially from lower current crude-oil prices.<sup>4</sup> Only when political forces have worked to unexpectedly weaken these refiners have we observed competition in the supply of crude oil, lower crude-oil production, and correspondingly higher crude-oil prices.

More basically, the direct governmental ownership or control over most of the world's crude-oil reserves, which began to emerge along with the "Seven Sisters" soon after WWI and accelerated after WWII, makes it natural to view an alliance of govern-

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<sup>3</sup>A very similar refiner-influence is what accounted for the turn-of-the-century monopolization of iron-ore achieved by the consolidation forming U.S. Steel. Not surprisingly, the contracting genius of J.D. Rockefeller was the source of the monopolizing merger (Thompson-Faith, 1984).

<sup>4</sup>This refiner-participation might suggest an output-decreasing monopsony-model rather than the output-increasing monopoly-model we are developing in this paper. However, our simple, monopoly-model can be rationalized by pointing to the British, Dutch, and U.S. governments, who have substantially constrained refiner organizations by making them serve the national interests of these governments. We shall elaborate upon this latter influence at various points in the text below.

ments as the underlying source of the world's Postwar crude-oil monopolies. Although the owners of the world's major oil refineries are typically citizens of their countries, this would not explain either the favoring of current over future generations of investors or the independent monopolizing activities of these popularly democratic governments. What would explain such activities is the fact that popular democracies are substantially biased towards favoring present over future generations of voters (Pigou). The corresponding political premium on high profits for current investors and low prices for current consumers, both of which result from artificially high levels of current oil production, would then induce these governments to favor an uncommitted crude-oil monopoly over competition and a world Pareto optimum.

Of course, neither governments nor organized refiners, viewed as unconstrained maximizers aiming at broader objectives, would ever want to exactly maximize the present value of the prospective profits from the production of crude oil. Nevertheless, modelling the maximization problem of governments or organized refiners in this broader, unconstrained, form would be unrealistic. For the observed broader decisionmakers typically delegate authority, including authority over crude-oil exploration or production decisions, to separate divisions. The only apparent goal of such divisions is the continuing (uncommitted) maximization of the division's asset values.

The broader initial goals of the conveniently evolved broader monopolizers are thus evidently best served when their specialized crude-oil decisionmakers, besides substantially ignoring their employers' broader interests, ignore their own time-inconsistencies, which means passively allowing the inconsistencies to be resolved in favor of future rationality.



Indeed, if this were not the case, owing to the effective equivalence of the pre-committed monopoly and competitive allocations, no one would ever rationally work to monopolize the crude-oil market. The only institutions that would rationally work to establish a crude-oil monopoly are institutions whose broader goals are served by employing a specialized division to exploit the time-inconsistencies inherent in such a monopoly.

### **C. A Simple Illustration**

Consider the market for heating oil. First imagine a perfectly competitive equilibrium. The currently extra-marginal barrel of the heavy crude oil ideally suited for refining into heating oil is withheld from this-year's market because next-year's expected price-cost margin is sufficiently greater than this-year's price-cost margin that the competitive supplier is just compensated for foregoing the interest that could be earned by devoting the heavy crude to this-year's market. This Hotelling equilibrium, of course, possesses all of the social efficiency properties of any perfectly competitive equilibrium.

Now assume that a specialized crude-oil monopolist -- say at the behest of the current refiners of heating oil -- emerges. The monopolist, initially keeping things exactly as they were, reviews the decision to withhold that last barrel of heavy crude oil from this-year's market. The same current revenues and costs that were obtained by the competitive supplier can be obtained by devoting the barrel to this-year's market. But the monopolist sees an additional increment of return to current production in that the revenue from all future sales will be enhanced due to the lower total quantity of crude oil available for sale in future markets. The effect is substantial, and a significant amount of the crude oil that perfect competitors were withholding for future markets will be advantageously sold at the

end of the current season.

Although the expectation of informed buyers that such monopolistic sales will occur substantially reduces the prices they are willing to pay earlier in the current season, these lower prices must be taken as amounting to an unavoidable loss, a fait accompli, to the narrowly-rational monopolist viewing the situation at the end of the current period. Only if the monopolist made a firm precommitment to producing the same initial total outputs as the original, competitive, sellers could the monopolist avoid this loss.

Extending the argument to a multi-period setting while retaining the realistic absence of such costly commitments, total monopoly outputs rise in each near-future period while necessarily falling in the many subsequent periods. This pattern generates lower crude-oil profits in the earlier periods that are only partially offset by higher crude-oil profits in the later periods, because the more favorable, present-value-maximizing, perfect-commitment, monopoly solution again approximates the competitive solution (e.g., again, Stiglitz and Lewis, Matthew, and Burness).

The above illustration applies to the actual decisions of a private crude-oil monopolist, such as the oil production manager of the early Standard Oil Trust. However, the actual decisions of more modern, governmental, monopolists have only occasionally reflected such micro-managed output decisions.

#### **D. Governmentally Managed Monopolies**

Governments do, however, regularly participate in making decisions with respect to the time that particular oil prospects are to be drilled. Here, the cartelized governments, as cooperating owners of a significant portion of the world's undeveloped oil lands, exploit

their leaders' democratic biases towards inexpensive oil products for current voters by setting up governmental agencies with a monopolistic misincentive to hasten the world-wide drilling of these prospects in order to raise the value of their intra-marginal -- i.e., future -- oil prospects. Such drilling-induced price-effects are, as one might suspect, qualitatively identical to the earlier-described, production-induced, price-effects. This is theoretically elaborated in Section III below.<sup>5</sup>

Thus, regarding the broader governmental decisions, once foreign interests had found significant reserves of crude oil, and the U.S. had begun to import significant quantities of crude oil, which occurred immediately after WWI, a remarkable confluence suddenly emerged in the expressed interests of the U.S. government and its large oil refiners (e.g., Chester). The jointly optimal strategy of the U.S. and its large refiners, as separate owners of substantial reserves of crude oil, then became one of setting up institutions that would induce other countries to sacrifice by currently both overdrilling and overproducing crude oil. The U.S. and its major integrated oil companies, as leaders of a monopolistic cartel, would each benefit, both in the present and in the future, from the contrived surplus of current crude oil and the contrived scarcity of future crude oil.

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<sup>5</sup>The government still has an opportunity to encourage oil production through various tax incentives. Although percentage depletion works in this direction, the corresponding government-induced discouragement to current oil production through the governmental government-induced tying of land royalties to current outputs works even more-so in the opposite direction. And, although observed U.S. drilling subsidies may be similarly rationalized by a governmental incentive to hasten the development of known oil fields, the existence of prospective future wartime price controls and rationing of oil products provides an alternative, later-discussed, sufficient rationale for the subsidization of such investments. All this supports our view the government fully achieves its desired hastening of oil production through a hastening of exploratory drilling on the world's various known oil prospects. The next subsection of the text will explain this otherwise implausible state of affairs.

### **E. The Nature of Cooperation**

This brings us to a critical point in the understanding of cooperative organizations. As pointed out in Thompson-Faith, the distributional results of jointly efficient cooperation are generally unfavorable to large groups of participants. Only the leaders of the cooperative are clear beneficiaries; others are generally kept in the cooperative by rationally predatory pre-commitments by the leaders. The original Rockefeller trust was formed by punishing hold-outs with artificially high transport charges resulting from prior rational contracts between Rockefeller and the railroads (Tarbell). Moreover, "independent" producers of crude oil, being rationally responsive to Rockefeller's pre-committed reaction function, must be formally regarded as part of the joint-maximizing cooperative. Their assent was entirely unnecessary. These independents, of course, were victimized by the cartel leaders, specifically because of their having to accept artificially high and intertemporally increasing overhead transportation charges and therefore significantly higher-than-competitive individual output decisions.

The aggressive Post-WWI governments leading their similarly "involuntary" cartels gained by inducing other governments to accept the sub-competitive crude-oil prices resulting from their centrally determined local drilling and production rates. Such centralized decisionmaking induced super-competitive oil drilling and production rates from foreign oil fields in the early, low-price, years, while allowing the cartel leaders to withhold much of their own exploration and production for the later, high-price, years. While predatory pre-commitments by cartel leaders kept foreign suppliers in the world's monopolistic cartel, these second-generation victims, like the first-generation victims, would have been much

better-off under simple competition.<sup>6</sup> These second-generation victims could not, even if it were a friction-less transaction, have compensated the cartel leaders for adopting competitive institutions. This is, again, because of the democratic undervaluation of future generations. (The obvious reason for the inability of the first-generation victims to compensate the cartel leader was simply the leader-refiner's increased profits from lower crude-oil prices.)

The informed domestic rate of resource-exploitation by private investors in the countries dominating the international cartel would be correspondingly delayed to take advantage of the artificially high internal rate of return to waiting. But small oil producers could hardly be expected to be so informed. Thus, as the first international cartel was formed from the mid-1920s through the early 1930s, and the real price of U.S. oil correspondingly fell, a false-expectational wave of oil-selling emerged among the independents. This in turn magnified an already existing technological external diseconomy on neighboring wells, especially in wildcatter-dominated Texas. The governmental response to this uninformed, wasteful, and contagious domestic over-production was for the U.S. to permit the states, again in combination with the relatively informed major oil companies, to efficiently ration-back domestic oil production, thereby giving essentially all influential oil observers (see, e.g., Blair) the indelible, yet quite false, impression that the government-supported crude-oil monopoly was predictably operating to reduce total output and raise world prices.

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<sup>6</sup>Viewing the issue historically, mistakes and all, probably reverses this distributional conclusion as regards the second-generation "victims". The heavy monopolistic exploration and production investment by cartel leaders in Third-world countries were unexpectedly nationalized in 1973 through appraisal principles that unrealistically assumed a perpetuation of the artificially low crude-oil prices previously paid by the leaders of the suddenly defunct cartel.

## II. GENERALIZING THE ENVIRONMENT

We now generalize the entire discussion, first by considering other functions of the state and other forms of time-inconsistency and later by exploring the technological and economic bounds of the above monopoly argument. The initial generalization shows how some cartels emerge, again with the state's blessing, not to foster monopoly but to efficiently induce the equivalents of perfectly competitive prices and outputs. The initial generalization will thereby help us provide a more balanced, and more self-contained, picture of governmental policy toward the oil industry.

### A. Perfect-Competition-Creating Cartels

When a state's very survival is critically dependent upon its ability to optimally resolve an ordinary time-inconsistency (i.e., to establish a pre-commitment favoring the present decisionmaker), the inconsistency will clearly have been so-resolved within observed, successfully surviving, states.

In particular, as elaborated elsewhere (Thompson, 1974, fn. 4; 1979, Sec. II.4), a major societal time-inconsistency threatening stable democratic states has concerned the magnitude of future governmental expenditures in prospective military emergencies. An optimal resolution of this societal time-inconsistency imposes future wartime price controls and rationing on certain goods. This, in turn, implies the optimality of prior peacetime subsidies to ordinary competitive investments in capital necessary for the future production of the war-rationed goods. Oil products have been quite significantly price-controlled and rationed during our most severe wars. A significant peacetime subsidy to U.S. oil investors is then a qualitatively efficient response to the potential problem of domestic

peacetime underinvestment, converting ordinary peacetime prices and incentives to after-subsidy prices and incentives equivalent to those that would exist under perfect competition (i.e., the prices and incentives that would exist if the need for future wartime rationing and price controls were somehow obviated by a lump-sum method of future emergency taxation.)

However, because of the domestic political resistance to directly subsidizing foreign capitalists, the domestically optimal aid to investors in foreign capital necessary for the production of war-rationed goods comes in an entirely different form. In particular, the importing government organizes an excess-capacity-inducing international cartel of foreign exporters of the war-rationed production. Such a cartel works by offering an above-market peacetime price to the foreign suppliers, but rationing back the resulting excess-supply, granting rights to sell at the above-market price in proportion to the excess capacities built up by the cartel members. This amounts to a subsidy to the foreign holding of this particular kind of capital. For all but the most severe wars, the induced peacetime build-up of excess capacity will exceed wartime demand; so wartime demand will be filled at prices that are not significantly higher than the cartel-augmented peacetime prices, and wartime rationing will be unnecessary. Indeed, if prices were not controlled and product rationed during the most severe wars, and the cartel correspondingly replaced by laissez faire, the pre-severe-war levels of investment, prices and capacity accumulation would all theoretically resemble the currently observed cartel levels. The cartel thereby works to create a perfectly competitive peacetime price pattern, the pattern that would arise if wartime prices could be allowed to rise to their perfectly competitive levels.

For example, our most recent, to-us-moderate, war in the Persian Gulf consumed a relatively large amount of oil but fortunately did not substantially increase oil prices because of the prior, OPEC-cartel-induced, excess capacity of oil production.

Other, earlier, international cartels -- those in tin, coffee, and sugar -- have been traditionally unfairly maligned by economists, who have mistakenly viewed these cartels as monopolistic despite the obvious cartel encouragement to investment and excess peacetime capacity and the fact that the U.S. has actively participated in the cartels by directly enforcing their capacity-based export quotas.

We are now prepared for a simple analysis of the dramatic changes occurring in the world oil market since the ignominious U.S. failure in Vietnam.

#### **B. The Vietnam Watershed**

The Vietnam War was a turning point in U.S. history. Besides suddenly ending a 200-year-old tradition establishing the effectiveness of the U.S. citizen-soldier -- the military tradition upon which the U.S.'s "rights-of-man" liberalism was founded (Hickson-Thompson, 1996) -- this unprecedented U.S. military failure led to: (a) a substantial increase in the commonly perceived U.S. military dependency on foreign oil; and (b) a new independence on the part of previous political dependencies. The latter effect, although partially reversing itself since the early-1980s, was sufficient to free the Middle-East from U.S. political domination and generate the observed rash of 1970s oil nationalizations. It was thus sufficient to transform the world oil market from a U.S.-run monopolistic cartel to a competitive peacetime market. The former effect, however, was also working, and created a new, U.S.-supported, excess-capacity-inducing, international cartel.



As explained in the above subsection, such a cartel merely works to create the equivalent of a perfectly competitive peacetime price pattern, one that would emerge if wartime taxation costs did not force oil importing countries to employ sub-competitive price-controls and rationing during their most severe defensive emergencies.<sup>7</sup>

Nevertheless, because economists have a profession-serving tradition of mis-analyzing these international cartels -- contentedly representing the cartels as examples of gross governmental inefficiency rather than acknowledging the subtle, perfect-competition-creating, efficiency of these pragmatically produced institutions -- a large majority of economists have been led to regard the OPEC cartel as a monopolistic cartel despite the availability of both an alternative interpretation described in the above subsection and a continuous stream of economic studies showing that OPEC possessed none of the organizational characteristics of a monopolistic cartel.<sup>8</sup>

Since OPEC members had sharply decreased their outputs, and this was indeed the primary cause of the increases in oil prices during the 1970s, economists could have alternatively inferred that the output-decreases are the result of a switch from an involuntary monopolistic cartel to competition in the world oil market. It would, as we have already

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<sup>7</sup>These two price-increasing effects were dominant despite the post-Vietnam-War decrease in the willingness of U.S. voters to collectively sacrifice for the benefit of their children, as reflected in the high growth in U.S. government debt and decrease in public expenditures on both welfare payments and elementary education, and resulting increase in the domestic U.S. political gains from monopolizing the world oil market. Nevertheless, this increase in the desire to monopolize the world oil market may be the most important long-term influence on the world oil market. In particular, if the gradual return toward world dominance and the trend toward non-oil-intensive warfare both continue, the real price of oil can be predicted to more than reverse its post-Vietnam-War increase.

<sup>8</sup>See, e.g., footnote 2.

argued, have been entirely consistent with the history of oil prices and the nature of crude-oil monopolization. All it would have taken is a realization that crude-oil monopolists faces a time-inconsistency. But, rather than providing a careful theoretical analysis of the effect of monopolization on the prices of natural resources, mainstream economists have continued to entertain themselves with a view of OPEC as an inept monopolistic cartel.

### **C. Technological and Economic Generality of the Monopoly Argument**

Although the above dynamic analysis obviously holds in a standard Hotelling environment, one implicitly containing a homogeneous stock of an exhaustible natural resource, it easily generalizes to an environment containing a heterogeneous stock of the exhaustible resource. This is done in Section III below.

Exhaustibility, then, is the sole essential characteristic of the resource under discussion. What "exhaustibility" introduces is, by definition, an intertemporal margin of substitution in which a greater current rate of utilization of a given resource presents the society with a lower future supply of the resource.

It is therefore tempting to extend the range of application of our monopoly argument, applying it to any industry in which a single firm is the sole owner of a kind of capital that is no longer worth producing. In the corresponding absence of replacement investment, and a specificity of the capital to a particular quality of output, this capital-and-output monopolist faces a time-inconsistent incentive to over-exploit the capital in the current period, generating supercompetitive current outputs and an excessive wearing out of the underlying capital stock.

Recall, however, that prospective output purchasers, those profiting from lower current output prices, must generally organize and work to prevent the above capital-monopolist from making an efficient commitment to produce a lower current output. The capital monopolist may, for example, want to promise to refrain from selling at prices below its initially advertised prices for an entire season. But such buyer-cooperation is generally illegal, at least as regards our domestic economy. So we suspect that our over-producing monopolists do not extend far beyond the oil industry, where the international scope and the intergenerational nature of the problem is sufficient for organized buyers to attract continuing governmental support for the exploitation of this "opportunity".

### III. A SIMPLE MODEL OF CRUDE-OIL MONOPOLIZATION

We think of the world as currently having  $W$  potentially profitable remaining oil wells. The current real cost of finding and developing the least expensive well is  $C_1$ , the next-least expensive is  $C_2, \dots$ , and the most expensive is  $C_W$ . As the relative drilling costs can be assumed to be invariant over time, and the consumption goods producible from the resources necessary to drill the 1st well can be taken as the numeraire in each period, each of these real drilling costs can be taken to be time-invariant.<sup>9</sup> The pros-

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<sup>9</sup>The numeraire consumption good is thus implicitly chosen to be a good whose marginal cost of production is not rationally expected to systematically change compared to the cost of drilling a given oil well. Expected future relative costs enter the problem as present certainty-equivalents. The possibility that the future world may simply not exist enters our problem by increasing the common discount rate applied to all future return and costs. Thus, although we may reasonably imagine 1000 years passing before our world's last oil well is exhausted and correspondingly estimate the probability of another millenium of human civilization (given a subjective probability of 499/500 of the world's surviving from one year to the next during the upcoming millenium) to be less than 1/7, the present-future tradeoff that defines our exhaustibility problem is no less relevant.

pective profit from any well is thus given by  $\pi_i(t) = P_t - C_i$ ,  $i = 1, \dots, W$ , where  $t$  represents the time at which the well is drilled, the simplifying assumption being that all profitable oil wells produce the same total output, which we take to be a unit of oil.

Figure 1 displays the technology, where the successive concave profit lines are, owing to the rationally expected time-invariance of the real drilling costs, all parallel to one another. Real prices rise over time, but, owing to the strong likelihood of increasing future substitutes (Nordhaus), at a decreasing rate. Given a positive real interest rate for each period,  $r_t$ , Figure 2 then superimposes on this technology a series of logarithmically parallel iso-present-value lines, the convex-from-below lines on the Figure reflecting a common investor-assumption that real interest rates will remain positive over time.

The resulting, competitive path of development is also shown in Figure 2 as  $\{t(1), t(2), \dots, t(W)\}$ .

Ricardo, and anyone in the oil business, would accept the graphically obvious implication that the prospects are exploited in the order of their potential profitability. Solow has recently argued the same point.

We now turn the entire industry (the sum of the above profits) over to a monopolist, one who is unable to make pre-commitments respecting future economic activities. The price of oil at any date depends upon the monopolist's decision variable, the number of wells in existence at that date.<sup>10</sup> While a given parameter to a competitive supplier, price is not a given parameter to the monopolist. In particular, the sooner the middle wells are drilled, the higher the price obtainable from any, given, later well.

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<sup>10</sup>Destroying a socially valuable resource is assumed to be strictly illegal.

FIGURE 1

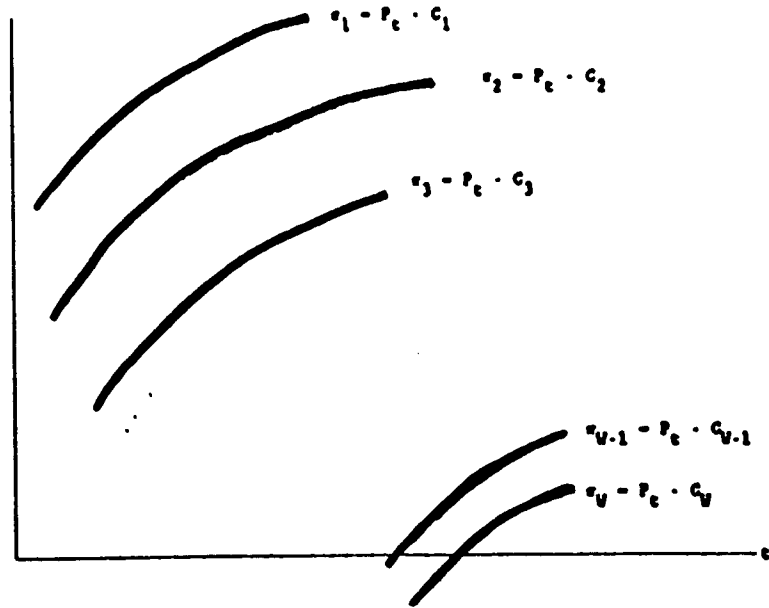
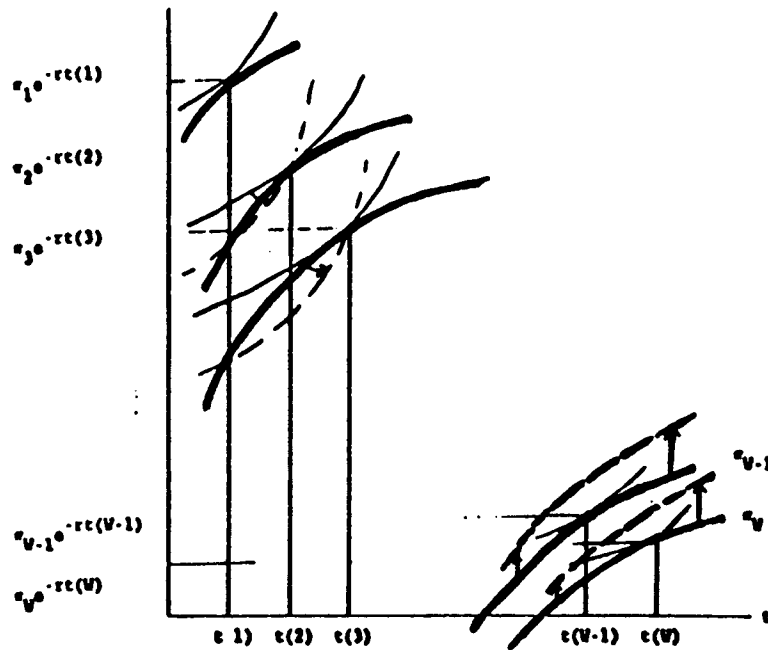


FIGURE 2



Although the prices of the earlier oil from the wells will correspondingly fall, these prices must be taken as given datum.

Thus, consider the monopolist's optimal drilling time for well #2, assuming that the monopolist takes over after well #1 is drilled and its product sold to final users, who hold oil inventories. First, for comparison,  $e^{-rt} (P_t - C_2)$ , the individual competitor's objective function for a constant  $r$ , yields a profit-maximizing level of  $t$  that satisfies

$$\begin{aligned} 0 &= e^{-rt} dP_t/dt + (P_t - C_2)de^{-rt}/dt \\ 0 &= e^{-rt} d\pi_2/dt - r\pi_2 e^{-rt} \\ (1) \quad r &= \frac{d\pi_2/dt}{\pi_2}, \text{ as in Figure 2.} \end{aligned}$$

In contrast, the monopolists' variable profit function is:

$$\sum_{i=1}^W \pi_i[t(i)]e^{-rt(i)} = \sum_{i=2}^W [P_{t(i)} - C_i]e^{-rt(i)}$$

Again, maximizing with respect to  $t(2)$ ,

$$\begin{aligned} 0 &= e^{-rt(2)} [d\pi_2/dt] - e^{-rt(2)} r\pi_2 + \sum_{i=3}^W \frac{[d\pi_i[t(i)]/e^{-rt(i)}]}{dt(2)} \\ (2) \quad r &= \frac{d\pi_2/dt}{\pi_2} + \frac{1}{e^{-rt}\pi_2} \sum_{i=3}^W \frac{d[\pi_2(t(i)) - e^{rt(i)}]}{dt(2)} \end{aligned}$$

The additional term on the right in equation (2), compared to equation (1), is unambiguously negative, signifying the fact that the later the drilling of well #2, the more oil there will be to compete with wells #3, ..., W.

Graphically, then, we need only transpose the additional term to the left and regard it as an increase in the marginal time cost of drilling well #2. The result, as is graphically obvious from the effective steepening of the originally tangent iso-profit curve to the monopolist's  $\pi_2$ -curve, the move to the broken-line iso-profit curve on Figure 2, is a hastening of the drilling of the #2 well by the monopolist and a corresponding decrease in current oil prices. Essentially the same argument applies to well #3, except for a very slight change in prices owing to: (a) the slight rise in price occasioned by the earlier drilling of well #2 and (b) the largely offsetting fall in price occasioned by the earlier drilling of wells #4, 5, etc.

While the same reason for hastened drilling applies with steadily decreasing strength to all further wells up until the last one, there is a gradually emerging possible counter-tendency toward delay based upon the accumulation of induced increases in distant future prices and corresponding twist up in the later prices and  $\pi_1$ -functions. Although this emerging twist-effect is dominated by the above-described hastening-effects for the earlier wells, after a while, the higher-future-price-effects may conceivably accumulate to the point that the possible delay due to the induced future price-twist may come to exceed the contemporaneous hastening-effect. This possibility is also illustrated on Figure 2, where the broken line illustrates the above-described upward twist in later prices, a shift potentially delaying the monopolist's drilling decision. However, since the levels of both of these later prices are also higher for the monopolist, earlier drilling is indicated for both wells because the firm would rather have the given increase in future revenue earlier than later. The price-twist resulting from the hastened prior production would therefore have to

outweigh both the basic monopolization effect and this simple impatience-effect in order for the drilling of a distant future well to be actually delayed.

#### **IV. POLICY REMEDY**

The governmental support for institutions generating the monopoly overproduction of crude oil, being based upon the well-known Pigouvian weakness of democracies in which future generations lack effective political representation, can be practically eliminated by a Constitutional Amendment eliminating the basic political imperfection responsible for all such inefficient exploitation of future generations (Thompson, 1996). Although such a reform would not significantly reduce the international contest over the rents from our world's resources, it would fundamentally improve the efficiency of our domestic economy.



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