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# On Capturing Oil Rents with a National Excise Tax

By THEODORE C. BERGSTROM\*

Everyone knows that in static competitive analysis the entire burden of an excise tax on a good in fixed supply falls on the supplier. Imposing a tax does not change the price paid by consumers and the price received by suppliers falls by the amount of the tax. One is tempted to conjecture that this result extends to the case of costlessly extracted depletable resources. Although the amount of such a resource that is supplied in any single period can change in response to variation in the intertemporal price structure, the total amount available for all time is fixed. Thus it is plausible that the effects of an excise tax imposed once and forever might be the same as in the static model.

This conjecture turns out to be true. In a Hotelling-type model with a costlessly extracted natural resource, if a uniform excise tax rate is collected from all consumers, the entire burden of the tax is borne by suppliers. This is the case whether the resource is supplied competitively or by a monopoly.

Where there are many consuming nations, there is unlikely to be perfect collusion among national governments in taxing away the rents of suppliers. It therefore is of interest to examine the implications of noncooperative behavior among consuming nations. Thus I consider a "Nash equilibrium" in which each nation chooses a tax rate which it cannot "improve upon" by unilateral action. I will show that this Nash equilibrium is characterized by a simple rule relating the equilibrium excise tax rates to demand elasticities and market shares.

My strategy is first to analyze tax incidence and optimal taxation in a static model and then to extend the results to the intertemporal case by establishing an isomor-

phism between the multiperiod and the one-period models.

## I. Static Competitive Analysis

Following common practice in the analysis of depletable resources, let us confine ourselves to a partial-equilibrium model. In this section there is only one time period, a natural resource, call it "oil," and a numeraire. There are  $n$  countries. Throughout the discussion it will be assumed that arbitrage possibilities establish a single "supply price"  $\bar{p}$  that suppliers receive regardless of the country in which they sell. Each country  $i$  imposes an excise tax on oil at the rate  $\theta_i$  expressed as a fraction of  $\bar{p}$ . Then the price paid for oil by consumers in country  $i$  is

$$(1) \quad p_i = \bar{p}(1 + \theta_i).$$

The total revenue from the excise tax is rebated to the citizens of country  $i$  in such a way that a consumer's rebate is essentially independent of his purchases of oil.

If all countries charged the same excise tax rate  $\theta$ , then consumers everywhere would pay the same price  $p$  for oil. Equilibrium in the oil market requires that

$$(2) \quad \sum_{i=1}^n D_i(p) = S,$$

where  $S$  is the fixed world supply of oil. Since  $D_i(p)$  is a decreasing function of  $p$  for all  $i$ , there is only one value of  $p$  that satisfies equation (2). This is true regardless of the level of  $\theta$ . Therefore the price  $p$  of oil to consumers is independent of the tax rate, and the price  $\bar{p} = p/(1 + \theta)$  received by suppliers is less than  $p$  by the amount of the excise tax per unit. Thus if the consuming nations were disjoint from the producing nations, they could extract nearly the entire economic rent from the suppliers by setting  $\theta$

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sufficiently large. There would be no "deadweight loss" since the consumer price is independent of  $\theta$ .

Suppose, instead, that each country sets its own excise tax rate and there is no cooperation among consuming nations, but each country believes that all other countries' tax rates are chosen independently of its own. The condition for market equilibrium is

$$(3) \quad \sum_i D_i(\bar{p}(1 + \theta_i)) = S.$$

If we totally differentiate equation (3) with respect to  $\theta_j$ , we obtain

$$(4) \quad \sum_i (1 + \theta_i) D'_i(p_i) d\bar{p} / d\theta_j + \bar{p} D'_j(p_j) = 0.$$

Manipulating expression (4) and recalling (1) we have:

$$(5) \quad (1/\bar{p})(d\bar{p}/d\theta_j) = -q_j \xi_j(p_j) / (1 + \theta_j) \left[ \sum_i q_i \xi_i(p_i) \right]$$

where for each  $i$ ,  $\xi_i(p_i) \equiv (p_i/q_i) D'_i(p_i)$  is the price elasticity of demand for oil in country  $i$ .

We can also calculate the effect of a unilateral change in country  $j$ 's excise tax rate on the price paid for oil by consumers in  $j$  and on oil consumption in  $j$ . Since  $p_j = (1 + \theta_j)\bar{p}$ , it follows that

$$(6) \quad (1/p_j)(dp_j/d\theta_j) = (1/\bar{p})(d\bar{p}/d\theta_j) + 1/(1 + \theta_j).$$

Substituting (5) into (6) yields

$$(7) \quad \frac{1}{p_j} \frac{dp_j}{d\theta_j} = \frac{1}{1 + \theta_j} \frac{\sum_{i \neq j} q_i \xi_i(p_i)}{\sum_i q_i \xi_i(p_i)}.$$

Using (7) and the fact that  $q_j = D_j(p_j)$ , one

can show that

$$(8) \quad \frac{1}{q_j} \frac{dq_j}{d\theta_j} = \frac{\xi_j(p_j)}{1 + \theta_j} \frac{\sum_{i \neq j} q_i \xi_i(p_i)}{\sum_i q_i \xi_i(p_i)}.$$

Since the price elasticities are all negative, we see from equations (5), (7), and (8) that the effect of an increase in country  $j$ 's excise tax rate is to lower the world supply price, raise the domestic price to the consumer, and lower domestic consumption of oil. To solve for a noncooperative equilibrium distribution of excise tax rates, we need to solve an "optimal tax problem" for each country. We define the excise tax and rebate policy to be optimal for country  $j$  if no unilateral change in that country's excise tax rate and in its distribution of rebates will benefit all citizens of country  $j$ .

For this analysis, let us assume a pure exchange economy in which consumer  $k$  in country  $j$  initially owns  $w_{jk}$  units of the numeraire and  $s_{jk}$  units of oil. Let  $s_j = \sum_k s_{jk}$  and let  $w_j = \sum_k w_{jk}$ .<sup>1</sup> A consumer allocation is described by the amounts  $c_{jk}$  and  $q_{jk}$  of numeraire and oil, respectively, consumed by each  $k$  in  $j$ . For any such allocation, let  $c_j = \sum_k c_{jk}$  and  $q_j = \sum_k q_{jk}$ .

Since the proceeds of the excise tax in country  $j$  can be returned to its citizens, the set of feasible consumption allocations for country  $j$  is the set of allocations for which total consumptions satisfy the trade balance equation:

$$(9) \quad c_j + \bar{p}q_j = w_j + \bar{p}s_j.$$

From (9) it follows that for any feasible rearrangement of consumption in response to a change in the excise tax,

$$(10) \quad dc_j/d\theta_j = (s_j - q_j) d\bar{p}/d\theta_j - \bar{p}dq_j/d\theta_j.$$

<sup>1</sup>This discussion of optimality could be simplified a bit and would yield the same results if we followed the trade theorists' custom of assuming that each country has only one consumer. Because there is abundant evidence that countries typically have more than one consumer, it seems worthwhile to demonstrate the result for the multiconsumer case. As the next two paragraphs show, this can be done quite easily.

Assuming that all consumers consume some of each good, the price  $p_j$  is the marginal rate of substitution of all consumers in  $j$  between oil and numeraire. Therefore we can conclude that a small increase in the excise tax together with a rebate that enables consumer  $k$  to move along a path where

$$(11) \quad dc_{jk}/d\theta_j > -p_j dq_{jk}/d\theta_j$$

will benefit consumer  $k$ . If a tax increase and rebate is found that satisfies (11) for all consumers  $k$  in  $j$  then everyone is benefited by the change. In this case, summing the expressions (11) over all  $k$  yields

$$(12) \quad dc_j/d\theta_j > -p_j dq_j/d\theta_j.$$

Substituting for  $dc_j/d\theta_j$  from the feasibility constraint in equation (10) and rearranging terms produces

$$(13) \quad (p_j - \bar{p})dq_j/d\theta_j > (q_j - s_j)d\bar{p}/d\theta_j.$$

Since  $p_j - \bar{p} = \theta_j \bar{p}$  and  $dq_j/d\theta_j < 0$ , equation (13) is equivalent to

$$(14) \quad \theta_j < [(q_j - s_j)(1/\bar{p})(d\bar{p}/d\theta_j)] / [q_j(1/q_j)(dq_j/d\theta_j)].$$

Therefore if the inequality in equation (14) holds, there is a feasible way to increase the excise tax and redistribute the proceeds so as to benefit everyone in country  $j$ . A similar argument shows that if the strict inequality in (14) were reversed, there would be a feasible way to benefit everyone in country  $j$  by lowering the excise tax rate and reallocating the proceeds. It follows that a necessary condition for  $\theta_j^*$  to be an optimal excise tax rate for country  $j$  is

$$(15) \quad \theta_j^* = [(q_j - s_j)(1/\bar{p})(d\bar{p}/d\theta_j)] / [q_j(1/q_j)(dq_j/d\theta_j)].$$

Recalling equations (5) and (8), we see that

(15) is equivalent to

$$(16) \quad \theta_j^* = -[1/\xi_j(p_j)][(q_j - s_j)/q_j] \times [q_j \xi_j(p_j)] / \left[ \sum_{i \neq j} q_i \xi_i(p_i) \right].$$

Thus the optimal tax rate for any country can be found by a simple computation from magnitudes for which empirical estimates exist. In case the price elasticities are nearly constant and identical across countries, equation (16) reduces to the even simpler expression:

$$(17) \quad \theta_j^* \simeq -\frac{1}{\xi} \frac{q - s_j}{\sum_{j \neq 1} q_i}.$$

## II. Intertemporal Competitive Analysis

Suppose that there are a countable, possibly infinite, number of time periods and that there is a constant interest rate,  $r$ . Let  $\bar{p}(t)$  be the price received by suppliers for oil supplied in period  $t$ . If there is a fixed total amount  $S$  of oil in the ground which can be costlessly extracted at any time, then, as is well known, competitive equilibrium can occur only where

$$(18) \quad \bar{p}(t) = \bar{p}(0)(1+r)^t.$$

Let  $\theta_i(t)$  be the excise tax rate on oil in country  $i$  at time  $t$ . Let

$$(19) \quad p_i(t) \equiv \bar{p}(t)(1 + \theta_i(t))$$

be the price paid by consumers in  $i$  at time  $t$  and let

$$(20) \quad \mathbf{p}_i \equiv (p_i(0), \dots, p_i(t), \dots).$$

Assume that demand for oil in country  $i$  at time  $t$  is a function:

$$(21) \quad q_i^t = D_i^t(\mathbf{p}_i).$$

If country  $i$  imposes a constant excise tax rate,  $\theta_i$ , in all periods, then from equations

(18) and (19) we see that

$$(22) \quad p_i(t) = \bar{p}(0)(1+r)^t(1+\theta_i).$$

Therefore the entire time path of prices  $p_i$  and hence total consumption over all time in country  $i$  is determined by  $\bar{p}(0)(1+\theta_i)$  and the exogenous interest rate,  $r$ . Thus we can define:

$$(23) \quad D_i^*(\bar{p}(0)(1+\theta_i)) = \sum_t D_i^t(\mathbf{p}_i),$$

where  $\mathbf{p}_i = (\bar{p}(0)(1+\theta_i), \bar{p}(0)(1+\theta_i)(1+r), \dots, \bar{p}(0)(1+\theta_i)(1+r)^t, \dots)$ . It then follows that the equilibrium condition equalizing world oil demand over all time with world supply is just

$$(24) \quad \sum_{i=1}^n D_i^*(\bar{p}(0)(1+\theta_i)) = S.$$

But comparing equations (24) and (3), we see that the intertemporal model just posed is isomorphic to the single period model that we studied. The same formal results apply. All that is left for us to do is to supply the economic interpretations of these results for the intertemporal model.

Suppose that all consuming nations impose a uniform excise tax rate on oil consumed at any time. Then from equation (22) we see that the price paid by consumers in all countries at time  $t$  is  $p(t) = \bar{p}(0)(1+r)^t(1+\theta)$ . From (24) we see that  $p(0)$  must satisfy

$$(25) \quad \sum_{i=1}^n D_i^*(p(0)) = S.$$

Thus the equilibrium price to consumers in period zero, and hence in all future periods, is independent of the excise tax rate. Therefore, just as in the static case, the entire burden of a uniformly imposed excise tax falls on the suppliers.

The comparative statics results in equations (5), (7) and (8) for single period analysis carry over to yield

$$(26) \quad (1/\bar{p}(0))(d\bar{p}(0)/d\theta_j) \\ = -q_j\xi_j^*/(1+\theta_j) \left[ \sum_i q_i\xi_i^* \right],$$

$$(27) \quad (1/p_j(0))(dp_j(0)/d\theta_j) \\ = \sum_{i \neq j} q_i\xi_i^*/(1+\theta_j) \left[ \sum_i q_i\xi_i^* \right],$$

$$(28) \quad (1/q_j)(dq_j/d\theta_j) \\ = \xi_j^* \left[ \sum_{i \neq j} q_i\xi_i^* \right] / (1+\theta_j) \left[ \sum_i q_i\xi_i^* \right],$$

where  $q_i \equiv \sum_t q_i^t$  and  $\xi_i^* = (q_i/p_i(0))D^{*'}(p_i)$ .

The trade balance equation (9) for each country must now be expressed in present value terms. That is,

$$(29) \quad \sum_t \left[ ((1/1+r))^t (c_j(t) + \bar{p}(t)q_j^t) \right] \\ = \sum_t \left[ ((1/1+r))^t (w_j(t) + \bar{p}(t)s_j(t)) \right],$$

where  $c_j(t)$  and  $q_j^t$  are consumptions of numeraire and oil in country  $j$  in period  $t$ , and  $w_j(t)$  and  $s_j(t)$  are amounts of numeraire and oil supplied by country  $j$  in period  $t$ . Recalling that  $\bar{p}(t) = \bar{p}(0)(1+r)^t$ , we can express (29) as:

$$(30) \quad C_j + \bar{p}(0)q_j = W_j + \bar{p}(0)s_j$$

where  $C_j$  and  $W_j$  are *present values* of total consumption and supplies of numeraire by country  $j$  and where  $q_j$  and  $s_j$  are *total* consumptions and supply oil by country  $j$ . Thus with appropriate interpretation, we retain the exact formalism of equation (9).

In competitive equilibrium all consumers in country  $j$  have a marginal rate of substitution,  $p_j(t)$  between consumption of oil and the numeraire in time  $t$  and a marginal rate of substitution of  $(1/(1+r))^t$  between consumption of numeraire at time  $t$  and numeraire at time 1. Therefore using the same kind of reasoning that developed (11) and (12), we can show that an increase in  $\theta_j$  with an appropriate distribution of the proceeds will benefit everyone in country  $j$  if

$$(31) \quad dC_j/d\theta_j > -p_jdq_j/d\theta_j.$$

From this point we reason exactly as in the

static analysis to show that a necessary condition for  $\theta_j$  to be optimal for country  $j$  is

$$(32) \quad \theta_j = -(1/\xi_j^*)(q_j - s_j/q_j)(q_j \xi_j^*) / \left[ \sum_{i \neq j} q_i \xi_i^* \right].$$

This expression is formally the same as equation (16). Here, however, we must keep in mind that  $q_j$  and  $s_j$  should be total consumption and supplies over all future time and  $\xi_j^*$  should be the "long-run" price elasticity. More specifically,  $\xi_j^*$  is the percent change in total consumption over all time that results from a permanent 1 percent increase in the present and in all future prices.

The optimal tax rate found in equation (32) has only been shown to be the optimal *constant* tax rate. More generally we could allow the possibility that a country could choose a schedule of changing tax rates over time. The analysis of a Nash equilibrium in varying strategies is, in general, much more difficult, both conceptually and as a matter of computation. I shall defer further consideration of these matters except to remark that, in the special case of stationary time-separable demand functions with a constant price elasticity of demand, there is a Nash equilibrium in which all countries find that a constant tax rate is the best response even if variable tax rates are possible.

### III. The Case of a Monopolistic Supplier

As in Section II, let us assume there are a countable number of time periods, a constant interest rate, and that oil can be extracted costlessly. Let us also suppose that resale possibilities are such that the monopolist is unable to charge different prices to different countries. Let  $\bar{p}(t)$  be the price the monopolist charges in time  $t$  and let  $\theta_i$  be the excise tax rate in country  $i$ .<sup>2</sup> Thus, as in Section II, the price paid by consumers in country  $i$  is  $p_i(t) = \bar{p}(t)(1 + \theta_i)$ . The vector of intertemporal prices to consumers is then  $\mathbf{p}_i$  as defined in equation (20) above. Assume

that the monopolist chooses a pricing policy over time so as to maximize the present value of his profits, since extraction is costless, his profits are

$$(33) \quad \sum_{t=0}^{\infty} \bar{p}(t) \left[ \sum_{i=1}^n D_i'(\mathbf{p}_i) \right] [1/(1+r)]^t,$$

subject to

$$(34) \quad \sum_{i=1}^n \sum_{t=0}^{\infty} D_i'(\mathbf{p}_i) = S,$$

If all consuming countries set the same excise tax rate,  $\theta$ , for all time, then in all periods,  $\bar{p}(t) = p(t)/(1 + \theta)$ . Thus the monopolist's profits in equation (33) can be rewritten

$$(35) \quad (1/1 + \theta) \sum_{t=0}^{\infty} p(t) \sum_{i=1}^n D_i'(\mathbf{p}_i) (1/1 + r)^t.$$

Since  $p(t)$  is a one-to-one function of  $\bar{p}(t)$ , we can view the monopolist as choosing  $p(t)$  so as to maximize (35). But then it is apparent from the form of (35) that the profit-maximizing level of  $p(t)$  is independent of  $\theta$ . Therefore we have the result that the level of a constant excise tax uniformly imposed in all countries has no effect on the price paid by consumers for oil. Since  $\bar{p}(t) = p(t)/(1 + \theta)$ , we see that almost all of the monopolist's profits can be taxed away by the consuming countries if they choose  $\theta$  sufficiently high.

In the interest of brevity, we omit the general analysis of noncooperative consuming nations and a monopolistic supplier. It is worth noticing, however, that in the special case of constant demand elasticity, as remarked by Joseph Stiglitz, a monopoly prices in the same way as do competitors. It is not hard to show in this case that the noncooperative equilibrium in excise taxes is the same as in the competitive case.

### IV. Comparing Actual and "Equilibrium" Excise Taxes

It is of interest to attempt empirical estimates of the responsiveness of world price and domestic price to an excise tax imposed

<sup>2</sup>In general a monopolist does not choose prices that rise at the interest rate.

TABLE 1—COMPUTING EQUILIBRIUM TAX RATES

Country <i>i</i>	Domestic Consumption in 1977 <sup>a</sup> (1)	Domestic Production in 1977 <sup>a</sup> (2)	Domestic Consumption as a Share of World Consumption (3)	$1 + \theta_j \frac{dp_j}{p_j} \frac{d\theta_j}{d\theta_j}$ (4)	Equilibrium Tax Rate	
					if $\xi^* = -1$ (5)	if $\xi^* = -.5$ (6)
United States	6,727	3,009	.30	.70	.24	.48
Japan	1,874	4	.08	.92	.09	.18
Germany	1,035	39	.05	.95	.05	.10
France	815	8	.04	.96	.04	.08
U.K.	686	271	.02	.98	.02	.04
Italy	720	7	.03	.97	.03	.06
EC	3,899	338	.175	.825	.21	.42
United States + Japan	12,490	3,351	.56	.44	.94	1.88

Source: Columns (1), (2), and (3) are taken from Table 6 of the *International Petroleum Annual*. Column (4) is computed using equation (27) of text. Columns (5) and (6) are computed from equation (32).

<sup>a</sup>Millions of barrels.

TABLE 2—ACTUAL AND "EQUILIBRIUM" TAX RATES (1977)

Country	Tax on Regular Gasoline in \$ per Gallon		Tax on Distillate #2 Fuel Oil in \$ per Gallon (3)	$\theta_j$ = Actual Net Tax Divided by Pre-Tax Retail Price		Equilibrium Tax Rate	
	Gross (1)	Net (2)		Gasoline (4)	Distillate (5)	if $\xi = -1$ (6)	if $\xi = -.5$ (7)
United States <sup>a</sup>	.13	.01	.13	.02	.27	.24	.43
Japan <sup>a</sup>	.61	negative	.29	negative	.47	.09	.18
Germany	.73	.13	.35	.21	.53	.05	.10
France	1.02	.48	.55	.73	.50	.04	.08
U.K.	.64	.40	.04	.78	.07	.02	.04
Italy	1.48	.93	.19	1.63	.43	.03	.06

Source: Columns (1), (3), (4), and (5) are taken from Table 15 of the *International Petroleum Annual*. Column (2) is computed from column (1) and data on government road expenditure and road user taxation found in *World Road Statistics*. Columns (6) and (7) are taken from columns (5) and (6) of Table 1.

<sup>a</sup>Numbers are for 1976.

in various countries. With these estimates we can check to see whether existing excise tax rates approximate the noncooperative equilibrium rates. From equation (32) we see that the numbers needed in order to make such estimates are the shares of the world's total oil consumption consumed and produced in the country of interest, and the long-run elasticity of demand for oil in each country. We make these estimates for the year 1977, the most recent year for which we have data.

Robert Pindyck estimates the long-run price elasticity of demand for petroleum

products to be about  $-1$  in all countries. Most other estimates place this number closer to  $-.5$ . If we use current shares of production and consumption as proxies for long-run shares, we can make estimates both for the case  $\xi_i^* = -1$  for all  $i$  and  $\xi_i^* = -.5$  for all  $i$ . These results are summarized in Table 1.<sup>3</sup>

<sup>3</sup>My estimates of the long-run shares of world oil consumption consumed in a country and produced in a country are actual 1977 shares. This of course is not entirely appropriate. The condition in equation (32) states equilibrium tax rates as a function of consumption and production shares when equilibrium excise tax

In Table 2, actual excise tax rates on gasoline and on distillate fuel oil are reported. It is not appropriate, however, to treat the entire tax on gasoline as an excise tax since governments also indirectly subsidize gasoline consumption by financing roads. To account for this effect, let us calculate a net tax on gasoline which is the difference between total road user taxes in the country (including fuel taxes, vehicle taxes, vehicle registration fees, etc.) and total road expenditure by local and central government in the country. We then divide net by total taxes and multiply by the gross tax rate reported in column (1) of Table 2 to obtain the net tax rate in column (2). While it is not hard to find reasons to quibble about this procedure, I suggest it as a reasonable first approximation.

Comparing columns (4) and (5) with either column (6) or column (7) suggests that there is at best little relation between actual excise tax rates and the noncooperative equilibrium optimal taxes. For the United States, the noncooperative equilibrium tax rate is estimated as approximately 25–50 percent. While the tax rate on distillate<sup>4</sup> and the gross tax rate on gasoline are about 27 percent, the net tax rate on gasoline when one allows for the subsidization of roads was only about 2 percent. On the other hand, the noncooperative equilibrium tax rate, even for the larger countries in Western Europe, is less than 10 percent while, almost without exception, they tax both gasoline and distillate at much

higher rates. If, however, one viewed the nine countries of the European Economic Community as acting cooperatively among themselves and noncooperatively with respect to the rest of the world, then their optimal tax rate would be between 20 and 40 percent. Examining columns (4) and (5), we see that excise tax rates for the European countries listed are for the most part higher than 40 percent. Japan spent about 40 percent more on roads than it collected in road user taxes in 1976 and did similarly in earlier years, 1973–75, for which data is presented. Thus it is reasonable to suppose that Japan on net subsidizes gasoline consumption while the optimal tax rate for Japan is almost 10 percent. On the other hand, Japan taxes distillate at almost 50 percent. It is interesting to observe that if the United States, Japan, and the EEC were to act cooperatively with each other and noncooperatively with respect to the rest of the world, the optimal tax rate in these places would be in the range 94–188 percent, somewhat higher than most current European tax rates and much higher than U.S. and Japanese rates.

#### V. Some Final Comments

In this paper I have assumed that there is a fixed supply of oil all of which can be extracted at zero cost. An easy extension of the results is to the case where there is a fixed supply of oil, all of which can be extracted at some constant positive cost. In this case, the arbitrage condition requires that the difference between the price and the extraction cost grow at the rate of interest. Essentially all of the results discussed above extend to this case where the excise tax is held as a constant fraction of the difference between price and extraction cost. A more realistic model, however, would have an array of oil deposits which can be extracted at differing costs. Analysis of tax incidence in such a model differs from the constant extraction cost model in much the same way that in a static model tax incidence is different when the supply schedule is not perfectly inelastic. Analysis where there is variable extraction cost raises a number of important

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rates are charged. Since current excise tax rates in the United States are lower, and in Western Europe are higher than equilibrium rates, we would expect that in equilibrium, the U.S. share of world consumption would be lower and European shares would be higher than is currently the case. Also, currently the United States produces about 15 percent of the world's oil but has only about 4 percent of the world's proven reserves. (These figures come from the *Oil and Gas Journal*, December 1978.) Therefore we might reasonably expect that in the long run the relative U.S. contribution to world supply would be lower than it currently is. These two considerations operate in opposite directions. While it is possible to make reasonable adjustments on both accounts, I resist the temptation to do so here.

<sup>4</sup>Distillate is used both as heating fuel, and as diesel fuel for motors.



issues which I intend to treat in another paper.

On the demand side of the market, I have considered two alternative assumptions. One is that the consuming countries act cooperatively, like a monopsonist. The other is that they act noncooperatively in a way analogous to Cournot oligopsony. On the supply side, I have considered two possible cases. One is where suppliers act competitively and the other is where they act monopolistically. Clearly there remains a good deal of interesting analysis to be done. For example, one would like to consider the theory of oligopolists confronting oligopsonists and to consider bargaining theories more subtle than simple noncooperative equilibrium.

In the construction of this model, I have assumed that the oil purchasing countries are indifferent to the levels and distribution of wealth outside their national borders. I have also ignored military and strategic considerations. Much of the political discussion surrounding "energy independence" for the United States suggests that these considerations may in the view of many people dominate the considerations studied here. It has been argued by some that most of the "rents" received by major oil producing nations accrue to a small and extremely wealthy ruling class. Such concentrated wealth may be used in capricious and dangerous ways, such as in financing international terrorism. Furthermore, the concentration of enormous mineral wealth in a militarily and politically unstable portion of the world is extremely tempting to potential invaders and increases the likelihood of war. To the extent that an excise tax on oil consumption reduces the

rents accruing to oil deposits, these pressures are reduced.

There has been a good deal of recent discussion about a proposal to impose a federal excise tax of \$.50 per gallon on gasoline consumption in the United States, with the revenue thus generated used to lower other taxes. Having warned the reader of many reasons to view our estimates of optimal tax rates as extremely crude, it is still hard to resist evaluating this proposal according to my estimates. According to these estimates, the optimal tax rate for the United States, if it acts noncooperatively with other consuming countries, is somewhere between 25 and 50 percent of the pre-tax price. As of this writing gasoline prices in the United States exceed one dollar per gallon. When one allows for the government subsidy of highways, gasoline currently is essentially untaxed. Therefore our estimates would suggest that currently an optimal tax rate for the United States, acting noncooperatively, might be on the order of \$.25 to \$.50 per gallon.

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