On Market Structure and the Taxation of Exhaustible Resources:

A Sales Tax, It Is Argued, Will Capture the Rents and Lower the Cut-off Grade of Ore Mined

By M. H. I. Dore*

ABSTRACT. The older static theory of the *taxation* of *exhaustible resources* is distinguished from the modern theory based on the work of *Harold Hotelling.* Both advocate some form of a *profits-based tax,* which is appropriate for conditions of *perfect competition.* But an oligopolistic *market structure* has additional *quasi-rents* which could be captured through taxation. It is argued that a *sales tax* will not only capture the *rents* but also lower the *cut-off grade* of the *ore mined.*

THE PAGES OF THIS JOURNAL reflect both an interest in and the importance of the taxation of exhaustible resources (see, for example, Curry, 1984, 1985a, 1985b; O'Faircheallaigh, 1986 and Dore, 1987a). This interest is based on a number of plausible grounds; one, that such resources are gifts of nature and that therefore they belong to the public domain; two, that uncontrolled and unfettered access to private enterprise could lead to either too rapid or too slow a rate of exploitation of the resources; and three, in the case of developing countries, the exhaustible resource is typically exploited by a foreign corporation that otherwise makes little contribution to the development of the country. Thus, either on the basis of equity or efficiency, some case is made for some form of state intervention. Tax intervention may take a variety of forms—auctioned licences, royalty payments, excise taxes, export taxes, or profits taxes.

The literature on this issue falls into two distinct categories. One is the vast literature on exhaustible resources that draws its inspiration from the work of Hotelling (1931). The other, which ignores Hotelling's dynamic framework, concentrates instead on incentive effects of particular tax schedules and finance for development. O'Faircheallaigh and Dore, cited above, as well as Garnaut and Ross (1983), belong to the latter category; here the concerns are fairly concrete, as they deal with particular countries and particular resources, mostly metals. However the framework is static.

* [M. H. I. Dore, Ph.D., is professor of economics, Brock University, St. Catharines, Ontario L2S 3A1, Canada, and Visiting Scholar, Cambridge University, England.]

American Journal of Economics and Sociology, Vol. 49, No. 4 (October, 1990).

But there are claims that the Hotelling-based literature is more "far-sighted," since it explicitly adopts a dynamic optimization framework. Examples of this are Burness (1976), Conrad and Hool (1981), Dasgupta and Heal (1979), Dasgupta, Heal and Stiglitz (1980), Dore and Harcourt (1986), Dore (1987b), Heaps (1985), Heaps and Helliwell (1985), and Lewis and Slade (1985). As might be expected, much of this literature is abstract and concerned with qualitative results under a special set of assumptions. With very few notable exceptions, much of this analysis is based on the assumption of perfect competition.

It is the objective of this paper to emphasize *imperfect* competition and to report, based on the author's previous work, how the standard Hotelling-based results that deal with the taxation of exhaustible resources turn out to be very different when the market structure assumed is not perfect competition but some form of oligopoly in which firms exercise a degree of market power in setting their prices. It is argued that this approach narrows the gap between the two categories referred to above, and might even justify the current practice which is based on indirect sales taxes, and to which most countries resort for ease of collection. On the other hand, the present approach may also be seen as a critique of the static theory as well as that of the Hotelling-based dynamic theory in so far as both are biased towards "profits-based" taxation.

Section I contains a synoptic restatement of some results in the taxation of exhaustible resources in the Hotelling-based theory, which assumes perfect competition. Section II surveys some qualitative results obtained under the assumption of oligopolistic behavior.

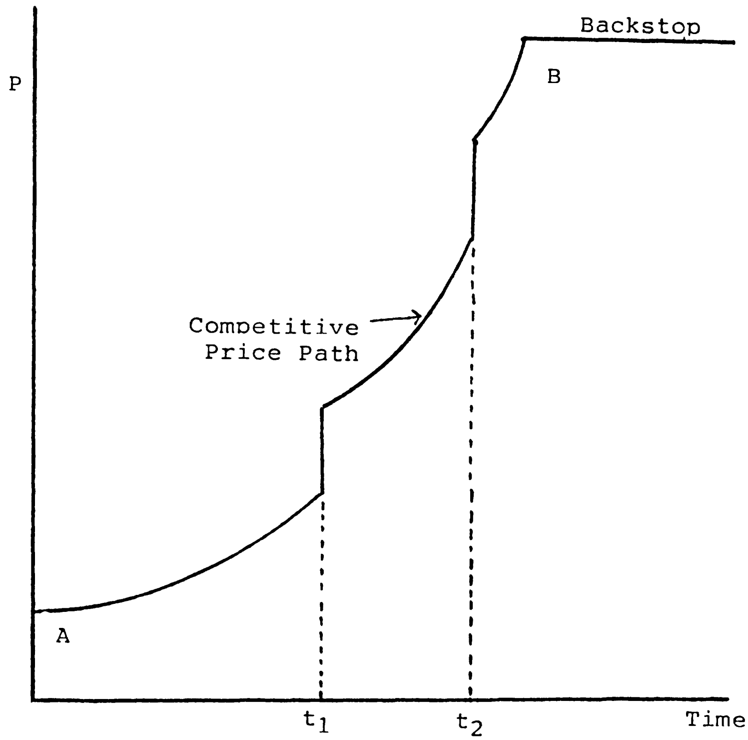
I

HOTELLING (1931) ESTABLISHED his fundamental result, which is the point of departure for all analysis of exhaustible resources carried out in a dynamic framework. He demonstrated that, in a competitive economy, the value of exhaustible resources is reflected in the price which appreciates at such a rate that the final unit of the exhaustible resource extracted costs the same as one unit of the alternative plentiful resource—the so-called "backstop" cost. However, this price is a function of known initial reserves. The larger these reserves the lower the price, and the lower the rate at which the price appreciates. Every new discovery leads to a discontinuous fall in the price, and technological breakthroughs, which reduce the cost of processing lower grade ore, have the same effect as the augmentation of the known reserves. On the other hand, as each low-cost grade of ore is exhausted, there may also be a discontinuous rise in the price as the next best grade of ore is mined.

Assuming perfect competition, let p be the price of the resource. The price appreciates at a constant rate r over time until time t_1, when the first (best) grade ore is exhausted. (Figure 1). Then the next best mine is exploited, and so on, until the final unit of ore costs as much as the alternative plentiful source (*e.g.* energy from the sun, or copper from the sea). Beyond this point, the price no longer rises, as it is not "exhaustibly" scarce.

Hotelling (1931) himself also considered the effect on output of a constant tax per unit of ore extracted. This is sometimes called a severance tax. On the assumption that the stock of the resource (say ore) is exogenously given, Hotelling found that the tax would induce a reduction in initial output and increase output in later periods (compared to the competitive no tax path of output). This change in the time profile of output is called *time-tilting* (Heaps and Helliwell, 1985, p. 423).

In particular, the tax will cause the resource to be extracted less rapidly when costs vary across industries. Similarly a subsidy that has the effect of reducing the unit extraction cost by some constant would lead to an increase in cumulative extraction. In other words, the tax or subsidy would be treated *as if* it raised or



lowered extraction cost exogenously, and so affected the time profile of output. This alteration of the time profile under conditions of perfect competition is considered to be a "distortion."

There is, in effect, a second distortion as well—a tax that alters the unit *cost* of production will also affect how much of the resource is extracted. Thus some resources will not be extracted even though their value before taxes exceeds the cost of extraction. This means the tax policy determines the lowest grade of ore that is mined. This (second) distortion is called ***high grading***. Any tax that induces either time-tilting or high-grading is called distortionary.

The effect of the imposition of a sales tax, which is a constant proportion of the price of the final product, would depend on what is happening to the discounted market price of the extracted ore. The extraction rate would increase if the market price of the extracted ore is rising, or decrease if it is falling. When the tax reduces the after tax return, then it is perceived as an exogenous increase in extraction cost, and it results in both time-tilting and high-grading.

The effect of an export tax is similarly distortionary as it reduces the after tax return.

There is only one tax, the profits-based tax, that both the static theory, as articulated (say) by Garnaut and Ross (1983), and the Hotelling-based dynamic theory, as articulated, for example, by Burness (1976) agree upon. Both schools of thought argue in favor of a profits-based tax.

Under conditions of perfect competition, even a progressive profits tax would be non-distortionary, as long as the after tax rate of return is at least equal to the (competitive) market rate of interest. Otherwise no new investments will be made in the extractive sector in the future.

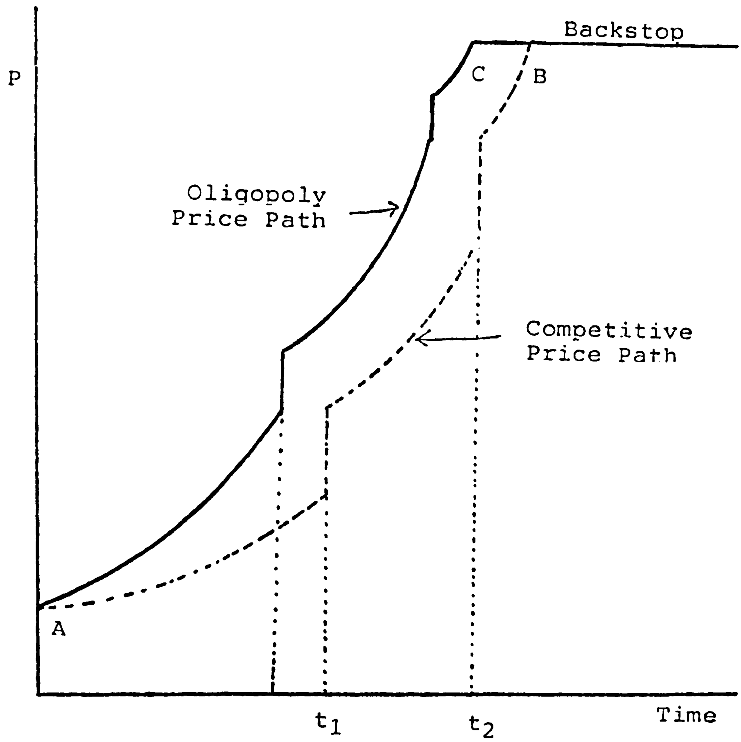
However, any result based on perfect competition is relevant only as a benchmark. For policy purposes it is important to take into account the market structure of the industry in question. In reality, most exhaustible resource industries (aluminum, gold, diamonds, copper, and oil) are oligopolistic. Most have some market power, which enables them to restrict output and charge prices which are higher than competitive prices. This conclusion is supported by the empirical work of Esposito and Esposito (1974) and Reynolds (1985, 1986). Indeed, once an oligopolistic firm installs excess capacity, or some other form of entry deterrence, the oligopolistic firm will behave as if it were a monopolist. This is the theoretical conclusion of the work of Wenders (1971), Spence (1977, 1980) and Salop (1979). Furthermore, Reynolds (1986) shows that, in the aluminum industry, a dominant firm equilibrium predicts the evolution of capital stock better than a Nash equilibrium, and that the excess capacity is the result of strategic investment.

Once the assumption of perfect competition is relaxed, Hotelling's fundamental result (illustrated in Figure 1) has to be modified. How this is done, is sketched below.

In a competitive economy, an exhaustible resource appreciates in value at the market rate of interest; that is, there is a true Ricardian resource rent due to the scarcity of the exhaustible resource that will be enjoyed by its owner.

However, in an oligopoly there are quasi-rents due to the market structure *as well as* true Ricardian resource rents. Hence price would be above the competitive price; furthermore, the price would appreciate at the market rate of interest *plus* some oligopoly premium z. That is, the resource appreciates at the rate r + z.

Figure 2 illustrates how under oligopoly the quasi-rents due to the market structure are added on to true Ricardian rents. Notice that the oligopolist practices high-grading, *i.e.* a mine is abandoned sooner than under perfect competition. Figure 2 is drawn on the assumption that the oligopoly ends when the backstop



cost is reached. The final units of the "scarce" ore may not be mined as the alternative which is plentiful becomes competitive much earlier because the oligopolist charges a higher price.

Here the (discounted) sum of quasi-rents and true rents is determined by (i) the unit resource rent, itself determined by the oligopoly's strategic price; (ii) the economic life of the mine; and (iii) the cost of production at each mine which is assumed to rise discontinuously at the exhaustion of each mine, right up to the backstop cost (see Figure 2). The higher each of these, the higher would be the discounted sum. This discounted sum may in fact be considered the capital value of the mine.

On the assumption that this capital value is known, it can be taxed via a fixed fee collected in advance, or a fee that varies as a proportion of the realized capital value per unit of time, *i.e.*, net profits per unit of time, suitably discounted. Under perfect competition (*i.e.*, when there are true Ricardian rents only but no quasi-rents due to market structure), the range of taxes that can be used is indeed wide, as has been argued by Dasgupta, Heal and Stiglitz (1980). However, under oligopolistic conditions there are some restrictions on the kind of taxes that can be used to capture the rents for the public sector. This is the subject of the next section.

II

SUPPOSE WE ASSUME that the elasticity of demand is n and it does not vary over time, *i.e.*, the analysis is confined to iso-elastic demand functions. This assumption is standard in the literature and requires no comment. Some effects of relaxing the assumption are considered in Dasgupta and Heal (1979).

Next, suppose that the oligopolist firm behaves as if it were a monopolist, once it has installed excess capacity or some other form of entry deterrence. The validity of this assumption has already been justified. The logical implication of this assumption is that an oligopolistic firm will have a target rate of return over and above the market rate of interest r, *i.e.*, the target rate is $r + z$, where $z > 0$ is the oligopoly premium. Finally, assume that the extraction cost is known with certainty.

These assumptions are enough to derive the proposition that the socially optimal tax is in fact a sales tax which is a function of the elasticity of demand.

By the second assumption, the oligopolist, behaving like a monopolist, sets output by equating marginal revenue MR with marginal cost MC. But

$$MR = (1 + 1/n)p \qquad [1]$$

where p is the price.

It can be shown that if the sales tax is set at $t = 1/(1 + n)$, then the divergence between MR and price p will vanish.[1] To increase profits, the firm must increase output, until MR = MC = p. This is illustrated in Figure 3 in which the shaded rectangle represents tax revenue. The oligopolist is now forced to increase output from q_1 to q_2.

As the oligopolist is forced to behave like a perfectly competitive firm, there is no time-tilting. In terms of Figure 2, the area between the curves AC and AB, which represented oligopoly profits, is now captured as tax revenue.

Let us now consider the effect of this tax on the cut-off grade of ore extracted. The "cut-off" grade of ore, g, from Figure 3 is given by the ratio of marginal revenue and marginal cost. Under competitive conditions the grade of ore g_c is:

$$g_c = MR/MC \qquad [2]$$

but as MR = p,

$$g_c = p/MC. \qquad [3]$$

However, under oligopoly output is determined by the elasticity of demand. Thus the cut-off grade under oligopoly g_m is:

$$g_m = (1 + 1/n)p/MC \qquad [4]$$

Therefore

$$g_m > g_c$$

However, after the tax, the divergence between MR and price vanishes, as argued above. Hence, as the oligopolistic firm is forced to increase output, it is also forced to lower the cut-off grade to g_c, the cut-off grade for competitive conditions.

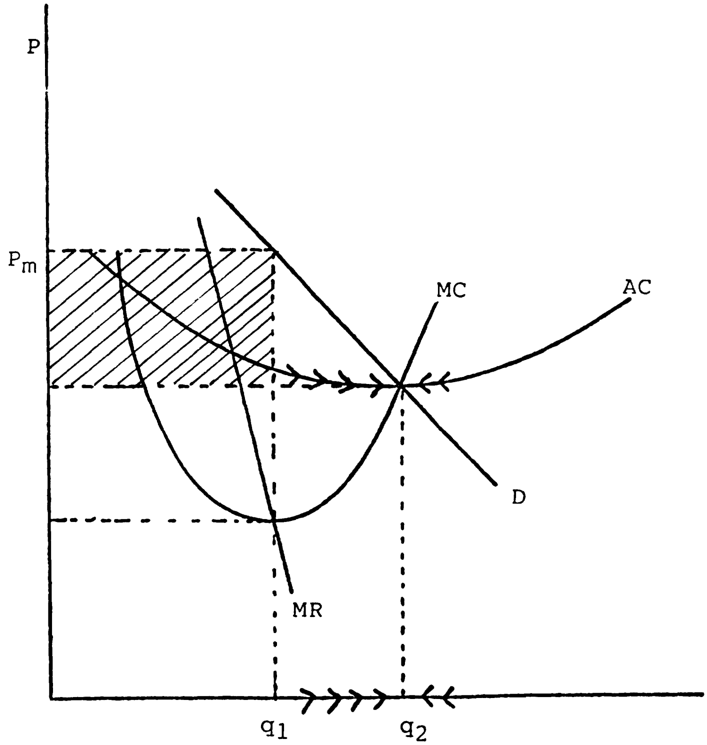
Thus the sales tax simultaneously meets the twin objectives of no time-tilting and no high-grading.

It can further be shown that a progressive profits tax would fail to capture the resource rents, as the increase in the tax rate is simply passed on as higher prices.[2]

III

Concluding Remarks

THE MAIN RESULT of this paper has been to show that a sales tax has properties unmatched by other taxes when applied to oligopolistic production of natural resources. Not only is such a tax simple but it has the advantage of dealing with



the considerable problem of high-grading in mineral extraction. Furthermore, the sales tax is simple to determine and easy to administer; only one parameter—the long-run elasticity of demand for the mineral—is required, and information on sales is easy to obtain.

For aluminum, for example, there are two published estimates for the elasticity of demand. Pindyck (1977) estimates the long-run elasticity to be 1.0, and Reynolds (1986) figures it to be 0.889. Using these estimates the optimal sales tax would range between 50% and 52%. As there is considerable evidence that the aluminum industry operates an administered price which has been remarkably stable in real terms over long periods (Dore, 1987a), such a tax rate would not seem out of line. Naturally such a tax cannot and should not be imposed piecemeal; it would have to be part of a comprehensive tax reform in which all other taxes, depletion allowances, royalties, etc. must be dropped and replaced with a single sales tax. It is interesting to note that an Australian study concluded that for the six year period 1967–1973, the Australian government's tax revenue from the mineral industry was negative due to a variety of tax concessions[3] applied to determine profits, on which taxes were assessed (Groenewegen, 1983).

The above analysis is subject to an important *ceteris paribus* assumption; nothing has been said about how an oligopolistic firm would react to a change in tax policy which moves away from profits, and implements a sales tax system. A more realistic analysis must consider reaction functions based on alternatives open to the firm. This is amply illustrated by the reaction of the oligopolistic aluminum industry to the introduction of a sales tax in Jamaica.[4] Nevertheless, these results cast some doubt on the widespread recommendations of profits-based taxes, such as the resource rent tax (for example, see Garnaut and Ross, 1983). Furthermore, Campbell and Lindner (1983) have already indicated the vast informational requirements of such profits-based resource rent taxes.

The results reported above might be viewed as a theoretical justification for sales taxes which are imposed for administrative convenience. For developing countries that do not have a sophisticated tax system, the sales tax would be an attractive alternative, with all the "right" theoretical properties.

Notes

1. As the tax rate is t, $0 < t < 1$, the firm receives $p(1 - t)$, *i.e.* $MR = (1 + 1/n)p(1 - t)$. But $t = 1/(1 + n)$, so that $(1 - t) = n/(n + 1)$ Therefore $MR = p$. Thus the divergence between MR and p disappears due to the sales tax. For a complete mathematical proof, see Dore (1987b).
2. The mathematics are a bit technical and are omitted here.
3. These were four main tax concessions: the deductibility for income tax purposes of subscriptions to mining shares; the exemption from income tax of profits from gold mining and of one-fifth of the profit in 30 prescribed minerals; the preferential treatment of capital expenditures in mining that would not normally be allowed to industry in general; and faster depreciation rates for capital items. These provisions all reduced taxable profits.
4. Jamaica, in 1974, introduced a tax on bauxite production which was designed to defeat the practice of transfer pricing. However, the oligopolistic industry was not only vertically integrated but also horizontally integrated. Hence it was able to reallocate production to other countries. For a full account see Dore (1987a).

References

Burness, H. S., 1976. "On the Taxation of Nonreplenishable Natural Resources," *Journal of Environmental Economics and Management*, 3, pp. 289–311.

Campbell, H. F. and Lindner, R. K., 1983. "On the Optimal Resource Rent Tax," *Economics Letters*, 13, pp. 263–368.

Conrad, R. F. and Hool, B., 1981. "Resource Taxation with Heterogeneous Quality and Endogenous Reserves," *Journal of Public Economics*, 16, pp. 17–33.

Curry, R. L. Jr., 1985a. "Mineral-Based Growth and Development-Generated Socioeconomic Problems in Botswana," *American Journal of Economics and Sociology*, 44 (3), July, pp. 319–36.

Curry, R. L. Jr., 1985b. "Problems Produced by the Growth Pattern of Botswana's Mineral-based Economy," "*American Journal of Economics and Sociology*," 44 (4), October, pp. 449–62.

Curry, R. L. Jr., 1984. "Problems in Acquiring Mineral Revenues for Financing Economic Development: a case study of Zambia," *American Journal of Economics and Sociology*, 43 (1), Jan., pp. 37–51.

Dasgupta, P. S., and Heal, G. M., 1979. *Economic Theory and Exhaustible Resources*, Cambridge: James Nisbet and Cambridge Univ. Press.

Dasgupta, P. S., Heal, G. M., and Stiglitz, J. E., 1980. "The Taxation of Exhaustible Resources" in G. A. Hughes and G. M. Heal, eds., *Public Policy and the Tax System*, London: George Allen and Unwin, pp. 150–72.

Dore, M. H. I., 1987a. "Mineral Taxation in Jamaica," *American Journal of Economics and Sociology*, Vol. 46, No. 2, April, pp. 179–203.

Dore, M. H. I., 1987b. "On the Taxation of Resources under Oligopoly," Brock University, mimeo.

Dore, M. H. I. and Harcourt, G. C., 1986. "A Note on the Taxation of Exhaustible Resources under Oligopoly," *Economics Letters*, Vol. 21 No. 1, 1986, pp. 81–84.

Esposito, F. F. and Esposito, L., 1974. "Excess Capacity in Market Structure," *Review of Economics and Statistics*, 56 (May), pp. 188–94.

Groenewegen, P. D., 1983. "Australian Tax Policy," in Gruen, F. H. ed., *Surveys of Australian Economics*, Vol. 3, Sydney: George Allen and Unwin.

Heaps, T., 1985. "The Taxation of Nonreplenishable Natural Resources Revisited," *Journal of Environmental Economics and Management*, 12, pp. 14–27.

Heaps, T. and Helliwell, J. F., 1985. "The Taxation of Nonreplenishable Natural Resources," in Auerbach, A. J. and Feldstein, M. (eds.), *Handbook of Public Economics*, Vol. 1, Amsterdam: North-Holland.

Hotelling, H., 1931. "The Economics of Exhaustible Resources," *Journal of Political Economy*, 9, pp. 137–75.

Lewis, T. R., and Slade, M. E., 1985. "The Effects of Price Controls, Taxes, and Subsidies on Exhaustible Resource Production" in Scott, A., ed., *Progress in Natural Resources*, Oxford: Clarendon Press, pp. 203–41.

O'Faircheallaigh, C. 1986. "Mineral Taxation, Mineral Revenues and Mine Investment in Zambia, 1964–83," "*American Journal of Economics and Sociology*," 45(1), Jan., pp. 53–67.

Pindyck, R. S., 1977. "Cartel Pricing and the Structure of the World Bauxite Market, *Bell Journal of Economics*, 8, pp. 335–38.

Reynolds, S., 1985. "Capacity, Output, and Sequential Entry: Comment," *American Economic Review*, 75, 4, September pp. 894–96.

Reynolds, S., 1986. "Strategical Capital Investment in the American Aluminum Industry," *Journal of Industrial Economics*, 34, 2 (March), pp. 225–45.

Salop, S. C., 1979. "Strategic Entry Deterrence," *American Economic Review*, 69, May, pp. 335–38.

Spence, A. M., 1977. "Entry, Capacity Investment and Oligopolistic Pricing," *Bell Journal of Economics*, 8, pp. 534–44.

Spence, A. M., 1980. "Notes on Advertising, Economies of Scale, and Entry Barriers," *Quarterly Journal of Economics*, 95, pp. 493–507.

Wenders, J. T., 1971. "Excess Capacity as a Barrier to Entry," *Journal of Industrial Economics*, 20, (1), pp. 14–19.