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THE TAXATION OF EXHAUSTIBLE RESOURCES

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The Taxation of Exhaustible Resources

ABSTRACT

This paper analyzes the effect of taxation on the intertemporal allocation of an exhaustible resource. A general framework within which a large variety of taxes can be analyzed is developed and then applied to a number of specific taxes. It is shown that there exists a pattern of taxation which can generate essentially any desired pattern of resource usage. Many tax policies, however, have effects which are markedly different both from the effects that these policies would have in the case of produced commodities and from those which they are designed (or widely thought) to have. For instance, if extraction costs are zero, a depletion allowance at a constant rate (widely thought to encourage the extraction of resources) has absolutely no effect; its gradual removal (usually thought to be preferable to a sudden removal) leads to faster rates of depletion (and lower prices) now, but higher prices in the future; which its sudden and unanticipated removal has absolutely no distortionary effect on the pattern of extraction. More generally, it is shown that the effects of tax structure on the patterns of extraction are critically dependent on expectations concerning future taxation. The changes in tax structure which have occurred in the past fifty years are of the kind that, if they were anticipated, (or if similar further changes are expected to occur in the future) lead to excessively fast exploitation of natural resources. However, if it is believed that current tax policies (including rates) will persist indefinitely, the current tax structure would lead to excessive conservationism. Thus, whether in fact current tax policies have lead to excessive conservationism is a moot question.

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1. Introduction

The recent and justly influential report of the Meade Committee on the reform of the U.K. tax system has highlighted the fact that the effects of taxation on patterns of resource-allocation are frequently complex and difficult to identify. Nowhere is this more true than in the field of natural resource taxation, where the general complexity is often compounded by the interactions of several different types of tax. Resource-based industries are frequently subject not only to conventional profits taxes, but also to royalties, revenue taxes, excess profits taxes and a variety of others, often with rather complex depreciation provisions. Meade (1975, p. 114 on) has argued in favor of the use of taxes as a policy instrument for controlling depletion rates.

The evaluation of such a proposal requires

a) an understanding of the way in which taxation alters the pattern of depletion of natural resources; and

b) an analysis of why the government might want to alter the rate of depletion from that which would occur in the market economy.[1]

This paper is concerned with the first problem: analyzing precisely the manner in which alternative taxes affect the pattern of resource extraction. On the one hand, we show that there exists a pattern of taxation which can generate essentially any desired pattern of resource usage. On the other, we show that many tax policies have effects which

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[1] For an analysis of this second question, see Stiglitz (1975a) and (1979) and Stiglitz *et. al.*, (1976).

are markedly different both from what those policies might have in the case of produced commodities and from those which they are designed (or widely thought) to have. For instance, if extraction costs are zero, a depletion allowance at a constant rate (widely thought to encourage the extraction of resources) has absolutely no effect; its **gradual** removal (usually thought to be preferable to a sudden removal) leads to faster rates of depletion now, but higher prices in the future; while its sudden and unanticipated removal has absolutely no distortionary effect on the pattern of extraction.[1]

In the next section we review some of the basic elements of the economic theory of exhaustible resources, and in particular characterize the pattern of resource use that would emerge in competitive markets in equilibrium in the absence of taxes or other distortions. This pattern will provide a benchmark, and subsequently we shall analyze the extent to which particular taxes cause departures from this benchmark. The competitive equilibrium pattern is, of course, efficient in the standard sense, and we shall therefore refer to departures from this pattern as biases or distortions.

One shortcoming of such an approach is, of course, that the actual situation before the introduction of a particular tax rarely corresponds to the distortion-free competitive equilibrium. There may be other taxes in existence, levied perhaps for redistributional reasons. The relevant markets may be imperfect or may be out of equilibrium. Besides these

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[1] The seeming perversities associated with taxation of natural resources were first noted by Hotelling (1931); the particular effects described below are noted in Stiglitz (1975a).

distortions, a number of others have been noted in the literature, including those arising from the "common pool" problem and inefficiencies associated with exploration.[1]

The impact of a tax in these environments may be quite different from that which it would have if imposed in the benchmark situations; indeed, some of the taxes that are imposed are designed to correct these distortions. In evaluating the particular proposals discussed below, this point must be borne in mind. However, we shall persist in working from the competitive equilibrium benchmark, partly because the selection of any initial condition here is arbitrary and this one at least has the sanction of convention, and partly because the methodology that we use to evaluate the distortions of different taxes can easily be adapted and applied to other initial situations.

2. The Tax-Free Outcome

There is now a substantial literature on the behavior of resource markets (see for example Dasgupta and Heal (1979)), so we shall content ourselves with a brief summary here. In particular we shall consider the case of a deposit of known size from which a resource can be extracted costlessly. This is the case which was considered by Hotelling (1931) in his seminal early work, and which gives rise to the famous "Hotelling Rule" that price should rise at the rate of interest in competitive equilibrium:

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[1] See, for instance, F. Peterson (1975) and Stiglitz (1975b) above.

$$\frac{\dot{P}_t}{P_t} = r \tag{1}$$

where P_t is the resource price at time t, $\dot{P}_t = dP_t/dt$, and r is the ruling interest rate. This result can be viewed either as an equilibrium condition in a market for flows, or as an equilibrium condition on a market for stocks, or as a necessary condition for efficiency. (Solow (1973) reviews these possible approaches very lucidly.)

The point about viewing (1) as an equilibrium condition in a market for flows of the good is that it ensures that the present value of the price, and hence of the profitability of a marginal unit, is the same at all dates. If this were not the case, then the market could clearly not be in equilibirum as sellers would then wish to rearrange the time-pattern of their sales. It is also very straightforward to see why (1) can be viewed as an asset market equilibrium condition. A resource is an asset which yields a rate of return only through price appreciation: this return is therefore given by $\dot{P}/P$, so that (1) merely requires the return on the resource to equal that on any other asset. Finally, it is clear that if the present value of the price is constant, then so is that of the marginal social product under competitive conditions with no externalities, a condition obviously needed for efficiency. Condition (1) is a necessary condition for competitive equilibrium: it is not sufficient. Necessary and sufficient conditions are that equation (1) holds, and that the initial price P_o of the resource is such that total consumption of the resource over the relevant time horizon (which we assume to be infinite) is just equal to the initial stock. Formally, we have

$$P_t = P_o \ e^{rt} \qquad \text{from (1)}$$

so that if D(P) is the demand for the resource at price P, and S is the total initial stock, we need

$$\int_o^\infty D(P_t) \ dt = \int_o^\infty D(P_o \ e^{rt}) \ dt = S \tag{2}$$

and this will in general define a unique initial price P^*_o, giving a price path as shown in figure 1. If P_o exceeded P^*_o then the price would be higher and consumption lower at every date, so that total demand would fall short of supply, and vice versa.

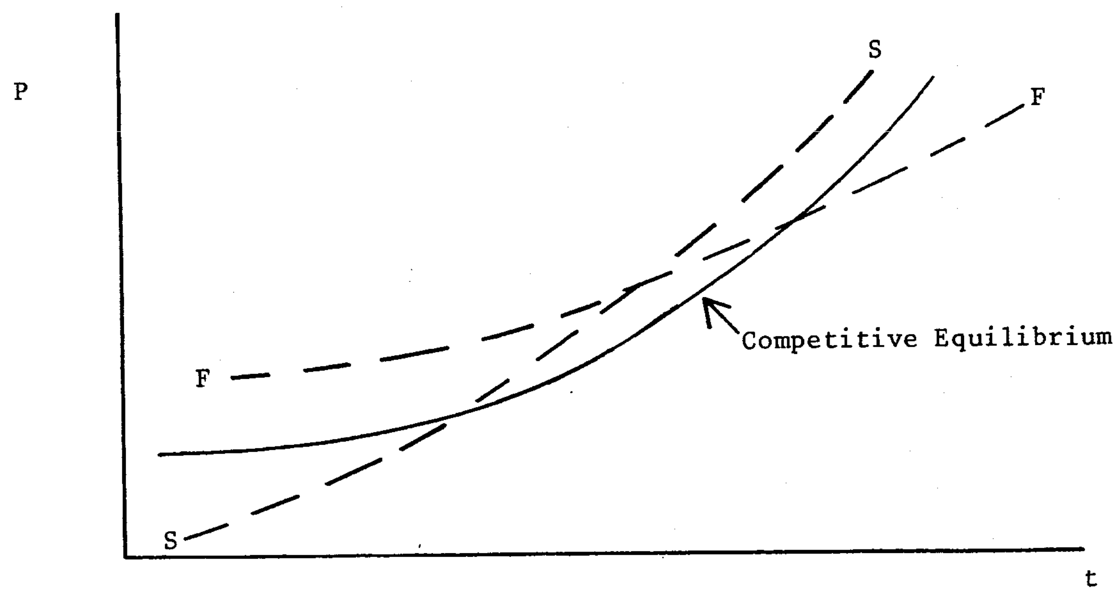

Figure 1

Let us now consider the effect of a distortion which makes the price rise at a rate different from r. In particular, suppose that for some reason $\dot{P}/P > r$, so that the price trajectory is steeper than that in competitive equilibrium. Then from the above arguments it is clear that the initial price must be below P^*_o. The point is simply that if it were not, then at every date the price on this alternative path would exceed that on the benchmark path, with consumption again less at every date and total demand over the time horizon falling short of total supply. Such a disequilibrium can be avoided only if the steeper path has the lower initial price. Similar arguments apply if for some reason the market price is made to rise less rapidly than the interest rate: in this case one has a flatter trajectory with a higher initial value. These two possibilities are shown as the paths SS and FF in figure 1.

It should be clear that if taxation results in a path such as SS, then the rate of consumption of the resource will be higher than it would be in competitive equilibrium. More formally, let C^*_t be the rate of consumption of the resource on the competitive path and C^s_t that on a path such as SS. Then for any $T' > o$,

$$\int_o^{T'} (C^s_t - C^*_t)\, dt > 0. \tag{3}$$

i.e. cumulative consumption up to any date is greater on a path such as SS. The proof is simple. Let T be the date at which the paths cross, i.e. $C^s_T = C^*_T$. Then clearly

$$\int_o^{T'} (C^s_t - C^*_t)\, dt > 0$$

for all $T' \leq T$. Equally, when $T' > T$,

$$\int_o^{T'} (C^s - C^*)\, dt = \int_o^T (C^s - C^*)\, dt + \int_T^{T'} (C^s - C^*)\, dt \qquad (4)$$

where we have suppressed time subscripts for convenience.

The first term on the right is positive: the second is clearly negative (as $p^s \gtrless p^*$ for $t \gtrless T$), and we have to show that it is less than the first term. We know that

$$\int_o^\infty (C^s - C^*)\, dt = 0$$

as cumulative consumption is the same on both paths. Hence

$$\int_T^\infty (C^s - C^*)\, dt = - \int_o^T (C^s - C^*)\, dt < 0$$

As $C^s_t - C^*_t < 0$, for any $T < t < \infty$,

then, for any $T' < \infty$,

$$\int_T^{T'} (C^s - C^*)\, dt > \int_T^\infty (C^s - C^*)\, dt$$

so that

$$\int_T^{T'} (C^s - C^*)\, dt > - \int_o^T (C^s - C^*)\, dt$$

or

$$\int_o^T (C^s - C^*)\, dt + \int_T^{T'} (C^s - C^*)\, dt > 0.$$

which, using (4), establishes (3). The converse relationship will obviously be true for a path such as FF. We have thus identified the biases or distortions that will result from paths different from the competitive one: paths such as SS will lead to more rapid resource use -- use that is excessively rapid from the point of view of economic efficiency -- and the opposite will be true of paths such as FF.

The above has been based on the assumption that marginal extraction costs for the resource concerned are zero. Before moving on to analyze the effects of particular taxes, we shall investigate briefly the effects of relaxing this assumption. Suppose instead, then, that there is a constant marginal extraction cost of b per unit. If P is the market price of the extracted resource, we denote by q the difference $P - b$, which in the absence of tax is also the profit from selling an extra unit of the resource. The equivalent of condition (1) is now just that[1]

$$\frac{\dot{q}(t)}{q(t)} = r \tag{5}$$

so that the marginal profitability is required to rise at the interest rate. The reasoning leading to this conclusion is quite analagous to that following (1), and one can analyze the effects of paths along which $\dot{q}/q \neq r$ as in figure 1. The integral of (5) is of course

$$P(t) = b(t) + (P(0) - b(0)\ e^{rt}$$

The term $q = p - b$ is frequently referred to as the royalty or rental on the resource.

Equation (5) can be solved for the rate of change of prices as a function of the extraction costs and the rate of interest:

$$\dot{p} = rp - rb + \dot{b} \tag{5'}$$

By exactly the same kind of reasoning as employed earlier, we can show Proposition 1: <u>if there exists two economies with the same initial stock of resources, S_o, but for which</u>

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[1] We use the notation $q(t)$ and q_t , etc., interchangeably.

a) $r_1(t) \geq r_2(t)$

b) $b_1(t) \leq b_2(t)$

c) $\dot{b}_1(t) \geq \dot{b}_2(t)$

then, there exists a $\hat{t}$, such that

$$p_1(t) \gtrless p_2(t) \quad \text{as} \quad t \gtrless \hat{t}$$

and

$$S_1(t) < S_2(t) \quad \text{for all} \quad t$$

where $S_i(t)$ represents the remaining stock in economy i at t.

Under these conditions, we can say that economy 1 is unabiguously less conservationist than economy 2. If one or two of the inequalities (a) - (c) are reversed, then it will not, in general, be possible to ascertain unambiguously whether economy 1 is more or less conservationist than economy 2.

This result is fundamental to the analysis of the intertemporal incidence of taxation on natural resources.

The effect of many taxes can be broken down into three components: the effect on the "effective interest rate" (the coefficient of p), the effect on the "effective extraction costs" and the rate of change of extraction costs (b).

More generally, we can establish <u>Proposition 2</u>. If we have two economies with the same initial stock of resources, and if

$$\dot{p}_i = \Psi_i(p_i, t)$$

with

$$\psi_1(p,t) > \psi_2(p,t) \qquad \text{all} \quad p,t,$$

then there exists a $\hat{t}$ such that

(i) $p_1(t) \lesseqgtr p_2(t)$ as $t \lesseqgtr \hat{t}$

and

(ii) $S_1(t) < S_2(t)$ for all t.

(ii) is an immediate consequence of (i). Assume (i) is not true, i.e. there exists t_1, t_2, $t_1 < t_2$ such that

$$p_1(t_1) > p_2(t_1)$$

and

$$p_1(t_2) < p_2(t_2)$$

Then there exists a $\tilde{t}$, $t_1 < \tilde{t} < t_2$, such that

$$p_1(\tilde{t}) = p_2(\tilde{t})$$

and

$$\dot{p}_1(\tilde{t}) \equiv \psi_1(p_1(\tilde{t}), \tilde{t}) < \psi_2(p_2(\tilde{t}), \tilde{t}) \equiv \dot{p}_2(\tilde{t})$$

which is impossible. This is the basic mathematical result which we shall use repeatedly.

As we shall see, the effects of various tax provisions often seem unintuitive, until one remembers that what is critical is the effect of the tax provision on the net return from extracting a unit today vis-a-vis the net return from extracting a unit tomorrow. Thus, if extraction costs were zero, a constant depletion allowance increases the net return today and tomorrow by exactly the same percentage, and hence, has no effect on the rate of extraction as we noted above. On the other hand, a reduction in the depletion allowance next period which is foreseen will lead, in the period prior to the reduction, to an increase in the rate of extraction, since the net return next period will be reduced, while the return this period is unaffected. If one is to eliminate the depletion allowance, one should do it quickly, not gradually, if one wishes to minimize the distortions in the intertemporal patterns of resource allocation.

The basic principle underlying the analysis of the incidence of taxation of natural resources was noted as early as 1914 by L. C. Gray in his classic article, "Rent Under the Assumption of Exhaustibility." The first mathematical analysis of the incidence of taxation is contained in Hotelling's classic article referred to earlier. The analysis was developed further in two recent conference volumes, M. Gaffney, Extractive Resources and Taxation (in particular, the papers by Vickrey and the editorial summary by Gaffney), and G. Brannon, Studies in Energy Tax Policy (in particular, the paper by Joseph Stiglitz[1]) and in a recent report to the Federal Energy Administration, "An Economic Analysis of the Depletion of Natural Resources," by Stiglitz, Dasgupta, Gilbert, and Heal.

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[1] This is an abbreviated version of Stiglitz (1973).

This paper presents a simple framework within which the effect of the various taxes and subsidies which have been analyzed in the earlier studies can be placed. To do this, we focus on the special case where (a) there are no capital costs of extraction and (b) the costs of extraction and the toal amount of the resource which is recoverable are not a function of the rate of extraction; (c) there is no exploratory activity. Many of the issues which were of central concern, e.g. in the Gaffney conference, are thus avoided in our analysis. We shall have a little to say about these issues in the concluding sections of our paper.

Moreover, we assume that the only instrument available to the government is taxation policy. Another critically important instrument is, of course, leasing policy. In practice, the distortionary affects of certain provisions of leases, e.g. diligence clauses,may be at least as great, if not greater, than those associated with tax policy, and these provisions may alter significantly the effect of tax policy on the rate of depletion. We shall not, however, be able to pursue these questions here.

Before presenting the analysis, we need to ask why the extractive industries have been the subject of special tax legislation.

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[1] See Stiglitz (1975b).

3. Special Provisions

The extractive industries have been the subject (beneficiary) of special provisions of the tax code. There are, for instance, two major provisions affecting the oil industry: depletion allowances (a certain fraction of the price received is deductible as an "allowance" for depletion) and the immediate write off of certain drilling expenses, expenses which, in other industries, would be considered to be capital expenditures and therefore subjected to depreciation over a number of years.

A number of rationale have been provided for this treatment. That some provision ought to be provided for depletion seems clear: an oil field is like any other asset; after it is used (the oil is taken out), it is worth less than before it is used; thus the gross revenues received are greater than the "net" income by an amount equal to the decrease in the value of the asset. That is why for all assets there is some provision made for depreciation.

Here, as in other areas of taxation, the essential difficulties arise in devising rules which both lead to economic efficiency and are judged to be fair and equitable. If the decline in the value of the asset (say the oil field) were continuously observable, then this decrease in the value of the oil field could simply be subtracted from the value of the gross returns to the oil company. This "depletion allowance" would in this context be equivalent to what has been called true economic depreciation in the context of durable capital goods.[1,2] This depletion allowance would provide an appropriate measure of net income and would, at the same time, be completely non-distortionary.

The difficulty arises from the unobservability of the change in the value of the asset (the oil field) on a year-to-year basis. (See Atkinson-Stiglitz 1980). Thus, simple rules have to be devised for "estimating" the depreciation. These "rules" tend to be equitable, providing, say, a lower effective rate of taxation on some classes of assets (say very long lived machines) than on other classes of assets, and, by the same token, to be distortionary, leading say, to greater durability than is optimal and to a relative expansion of industries with long lived capital goods.

For industries other than extractive industries, the basis of depreciating is usually the purchase price. For extractive industries, the depletion allowance is not based on the purchase price, but rather is based on the actual sales of the natural resource. In certain contexts, this would correspond to true economic depletion (Stiglitz, 1973); for instance, if the rate of interest were zero, then a 100% depletion allowance would correspond to true economic depletion. More generally if the aggregate stock of the resource is S and the price is p, and extraction costs were negligible, true economic depletion would be equal to

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[1] See Samuelson (1974) and Atkinson and Stiglitz (1980) for a discussion of the concept of true economic depreciation. For an application of this principle to natural resources, see Stiglitz (1973).

[2] This will be non-distortionary provided interest income is taxed. If interest income is not taxed, then immediate write off of all capital expenditures is non-distortionary: the tax is simply a pure profits tax. See Stiglitz (1976) and Atkinson and Stiglitz (1980).

$$-\frac{dpS}{dt} = -\dot{p}S - \dot{S}p = pR(1 - \frac{\dot{p}}{p}\frac{S}{R}) \quad \text{i.e.} \quad \frac{\dot{p}}{p}\frac{S}{R}$$

where R is the rate of resource extraction ($= -\dot{S}$), S/R is the number of years supply left at current rates of extraction, and $\dot{p}/p$ is the rate of increase in prices. Thus if real prices are rising at the rate of 2% and each year we extract 3% of the stock, then the true economic depletion rate, expressed as a fraction of the value of current extraction is 33%.

Clearly, for particular fields and particular industries, any particular depletion rate is likely to be overgenerous and, for others, to be less than "fair." Moreover, these provisions expressing the depletion allowance in terms of the value of the output may have distortionary effects; the examination of these effects is one of the focal points of this paper. The question remains, however, why for extractive industries the basis for depletion (depreciation) seems so different than for other industries. Why not simply base depletion allowances on the costs of acquisition of the asset?

The answer, we suspect, has to do with the large variability in the ratio of the value of the asset to the cost of acquisition: some oil fields turn out to have a great deal of oil, others very little. Although the cost of acquiring the lease may systematically be related to the amount of oil in the field, the correlation is low. Thus, if the cost of acquisition were the basis for depletion, then any firm which discovered that it had a good well would resell the well to another firm (perhaps a subsidiary) at the market value of the (now known) oil contained in it, realizing the capital gain (which would be subjected to the favorable capital gains tax treatment). This would then provide a higher basis for depreciation (depletion). Basing depletion on sales, rather than on costs of acquisition, avoids these tax induced transfers of ownership of natural resources.[1]

Thus, providing <u>some</u> allowance for depletion and basing that allowance on actual extraction (rather than, as in other industries, on the cost of acquisition of the asset) need not be viewed as a special gift to the extractive resource industries. Economic efficiency requires that some depletion allowance be provided, and, given the differences between extractive industries and other industries, that the form of the allowance should differ is not surprising. What we have to ask, however, is whether the particular form and level at which those allowances are presently provided are both equitable and non-distortionary.

There have been some other arguments put forward for why extractive industries ought to be taxed differently from other industries.

The first and most persuasive argument, in our judgment, is associated with the fact that most of the income generated in extractive resource industries is really a rent; the taxation of rents is non-distortionary (if done in the appropriate way). Thus, the minimization of the dead weight loss associated with the total tax system may entail extractive industries being taxed at a higher rate than other industries. (See Stiglitz, 1975.)

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[1] These may be undesirable, not only because of the extra transaction costs to which they give rise, but also because they may lead to economic inefficiencies: even if the original owner were the most efficient extractor of that oil, it might pay him to sell the field.

A second argument is associated with some of the market imperfections noted earlier; in particular, incentives for private returns from oil exploration may be less than social returns, and thus some subsidization to exploration may be desirable. (See, for instance, Stiglitz, et. al. 1978, Volume 3, ch. 1.)

The argument put forward most frequently by proponents of the special treatment are that the extractive industries are more capital intensive and riskier than other industries, and the present tax code discriminates against capital intensive and risky industries. These arguments have, however, been shown to be at best suspect: there is little evidence that the extractive industries are riskier (in the relevant sense) than other industries and there is strong theoretical arguments suggesting that the present tax system does not discriminate against risky (Mossin (1968) , Stiglitz (1969)) or capital intensive industries (Stiglitz (1976)).

In the remainder of this paper, we put aside these normative questions, focusing simply on the descriptive analysis of the effects of various taxes on the patterns of extraction.

4. A Profits Tax

We begin our study of particular taxes by looking at the profits tax, a tax which impinges on almost all resource-using industries. We might also refer to this as a "rental" or "royalty" tax, as in the context of the simple model above it is levied on the profit $q = p - b$ per unit. Let τ be the rate of tax on this rental or profit: then the after-tax return to the producer is

$$q_t (1 - \tau_t) = (P_t - b)(1 - \tau_t)$$

In competitive equilibrium this must grow at the rate of interest, so that

$$\frac{\dot{q}_t (1 - \tau_t) - q_t \dot{\tau}}{q_t (1 - \tau_t)} = r \qquad (6)$$

Rewriting (6) as

$$\dot{p} = p[r + \frac{\dot{\tau}}{1 - \tau}] - b(r + \frac{\dot{\tau}}{1 - \tau}) \qquad (6')$$

we can immediately apply Proposition 1, Section 2, to see that the tax has no effect if $\dot{\tau} = 0$; if $\dot{\tau} > (<) 0$, the effect is equivalent to a rise (fall) in the rate of interest. Thus, a rising tax rate encourages consumption today, a falling tax rate discourages it.

(At one level, then, a constant profit tax is non-distortionary. However, a warning is in order: a reduction in profits, by lowering the overall return on capital employed in the industry, will presumably affect its willingness to allocate funds to exploration and to the development of new mines and wells. In the long run such an effect could be important: its magnitude will of course depend on the treatment of exploration and development expenses for tax purposes.)

So far we have considered a situation where the profits tax is applied to profits from selling the resource, but not to interest income.[1] Often it will in fact be applied to both, causing the effective rate of return to companies to be $r(1 - \tau_t)$ so that (6') becomes

$$\dot{p} = p[r(1 - \tau) + \frac{\dot{\tau}}{1 - \tau}] - b(r(1 - \tau) + \frac{\dot{\tau}}{1 - \tau})$$

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[1] If interest payments by firms are tax deductible, at the margin, the cost of capital remains r.

We can immediately apply Proposition 1 to show that if $\tau \geq 0$ and $\dot{\tau} \leq 0$, then the tax encourages excessive conservationism, while if $\dot{\tau} > 0$, the effects are ambiguous.

There is a simple verbal argument which makes clear the intuitive basis of the main propositions of this section. In the pre-tax situation, the profit realized per unit of sales rises over time at the interest rate as therefore does the tax liability per unit if a constant rate of profit tax is introduced only on profits from sales. In this case the present value of the tax liability incurred by the sale of a unit is a constant, independent of the date of the sale. There is therefore no reason why the introduction of a tax should lead a producer to change the sales profile that he wishes to adopt. If on the other hand the tax rate is rising, then so clearly is the present value of the tax liability per unit sold, and this induces a producer to bring sales forward to minimize his tax liability, and vice versa: hence the distortions associated with changing tax rates.

5. A Sales Tax

We now consider a tax on the value of resource sales. In this case extraction costs are not deductible in computing tax liabilities, so that the return to the producer from selling a unit is

$$P_t (1 - \tau_t) - b$$

or

$$(1 - \tau_t) [P_t - b/(1 - \tau_t]\,.$$

This must rise at the rate of interest. Let

$$\hat{b} = b/1 - \tau_t$$

Then the "taxed" economy is clearly equivalent to an untaxed economy in which

$$b_t^* = \hat{b}_t > b$$

and

$$r_t^* = r_t + \frac{\dot{\tau}}{1 - \tau}$$

Using Proposition 1, we see that the taxed economy is more conservationist if, for all t

$$\tau \geq 0$$

$$\dot{\tau} \leq 0$$

In this case it is easy to characterize the set of tax-paths which are intertemporally neutral; they satisfy the differential equation

$$\dot{\tau} = \frac{b\tau r}{p}$$

Thus, if $b = 0$, any constant tax rate will do.

An alternative form of taxation often levied on resource-producers is a royalty: this is typically a payment of a certain percentage of the value of a resource extracted. For example, oil companies operating in the U.K. currently have to pay a royalty of 12% of the value of any petroleum "won and saved" from U.K. fields in each half-year. Such a royalty is obviously a tax on the gross revenues from resource sales, and is therefore equivalent to a sales tax levied at a rate of 12% on the final price: all of the conclusions of the earlier parts of this section are then applicable. In particular, a constant rate of royalty will lead to a postponement of consumption and production. As in the case of a profits tax, there is again a simple verbal argument that conveys the main point. If the difference between sale price and extraction cost rises at the interest rate (and the extraction cost is constant), then the price rises at less than this rate. Hence the present value of the tax liabilities based on the price will fall, providing sellers with an incentive to postpone production.

6. The Depletion Allowance

Under United States tax law, the tax liability of an oil company is based on its trading profits minus an amount known as the depletion allowance. This allowance is proportional to the depletion of the company's oil reserves during the year under consideration, i.e. to the value of its sales. Thus it is simply equivalent to a negative sales tax. The analysis of the preceeding section is thus directly applicable: It encourages excessively fast exploitation of the resource and its graduate removal exacerbates this effect. Again there is a simple intuitive explanation of these effects.

The value of such an allowance to the producing firms varies as the price of the resource changes, and in particular rises with price over time. But with positive extraction costs, consumer price rises less rapidly than the rate of interest, and in consequence the present value of the depletion allowance falls. The tax saved by a one-unit depletion today has a greater present value than that saved by a one-unit depletion in the future, providing a clear incentive to deplete sooner rather than later.

Note that a constant rate of depletion allowance introduces no distortion in the pace of extraction if the price of unextracted resource is used to value the depletion. Let τ be the rate of profit taxation and let α $(0 \leq \alpha \leq 1)$ denote the percentage of depletion allowance, where 'depletion' is computed as the market value of the rate of extraction using the unextracted resource price to compute this value. Then if x_t is the net return to the seller from one unit,

$$x_t = (P_t - b)(1 - \tau) + \alpha\tau x_t$$

and therefore

$$x_t = (P_t - b)(1 - \tau)/(1 - \alpha\tau).$$

By the arbitrage equation (5) we have that

$$\dot{x}_t/x_t = \dot{P}_t/(P_t - b) = r$$

But $\dot{P}/(P - b)$ is just $\dot{q}/q$, so that the allowance introduces no bias. With $\alpha < 1$ it merely reduces the value of total profits.

7. The Taxation of Capital Gains and Losses

The return from holding an exhaustible resource comes, as we have seen, entirely in the form of capital gains. Because of the difficulty of estimating unrealized capital gains, virtually all countries tax capital gains only upon realization. But in the case of natural resources, if the realization takes the form of "extraction" (selling the oil above ground) rather than transferring ownership of oil below ground, it is not subjected to capital gains but to ordinary income taxation (but it benefits from the depletion allowance, which we have just discussed.) On the other hand, the value of land under which there is oil depends critically on the amount of oil underneath it. Thus, if oil has been extracted from a pool, the value of the land will be correspondingly decreased. If the owners of such assets are allowed to deduct the capital loss, this, combined with the other provisions discussed, may give rise to significant distortions in the patterns of extraction.

Consider, for instance, a field, the oil from which, for simplicity, we shall assume will be extracted at a single point of time, when the rate of increase in (net) return from selling the oil is equal to the rate of interest. Clearly, the firm will, before the date at which extraction occurs, never realize its capital gains (the usual "locked in effect"). Since at extraction, it will be subjected to income taxation, the tax on capital gains can be avoided completely if the firm which makes the original discovery also does the extraction. After extraction, the land (lease) can be resold, with the firm experiencing a capital loss. Since the present value of this tax savings is reduced the longer that extraction is delayed, this provision leads to a <u>faster</u> rate of extraction. In effect, it is like a depletion allowance, not related to the current price but to a fixed price (the price of acquisition of the asset.)

If all oil fields had the same purchase price, then for the rate of increase of net returns to be equal to the rate of interest, we would require

$$\frac{\dot{p}}{p - b + d} = r$$

where d is the "tax savings" from the sale of the land: effectively the cost of extraction is lowered, and this increases the rate of extraction.

In fact, different oil wells have different costs of extraction. This introduces a set of distortions which we have not yet discussed. In all of the models presented thus far, we have assumed all oil wells have exactly the same costs of extraction. In fact, of course, there are different costs associated with different fields; it is well known that the optimal way of extracting the oil is to extract it from the cheapest source first (effectively, the total present discounted value of extraction costs is minimized in this way). In all of the cases examined so far, this basic principle still obtains: although the taxes interfere with the intertemporal pattern of extraction, cheap wells will always be used before more expensive wells. This is not the case here. What the firm is concerned with is its "net" cost of extraction, $b - d$; what society is concerned with is the social cost of extraction b. The two may be markedly different. Thus, d will be low (possibly even negative) for land acquired a long time ago, high for land acquired recently; d will be high for leases acquired when the firm was over optimistic about the amount of oil contained in the lease[1] relative to cases where it was over pessimistic.

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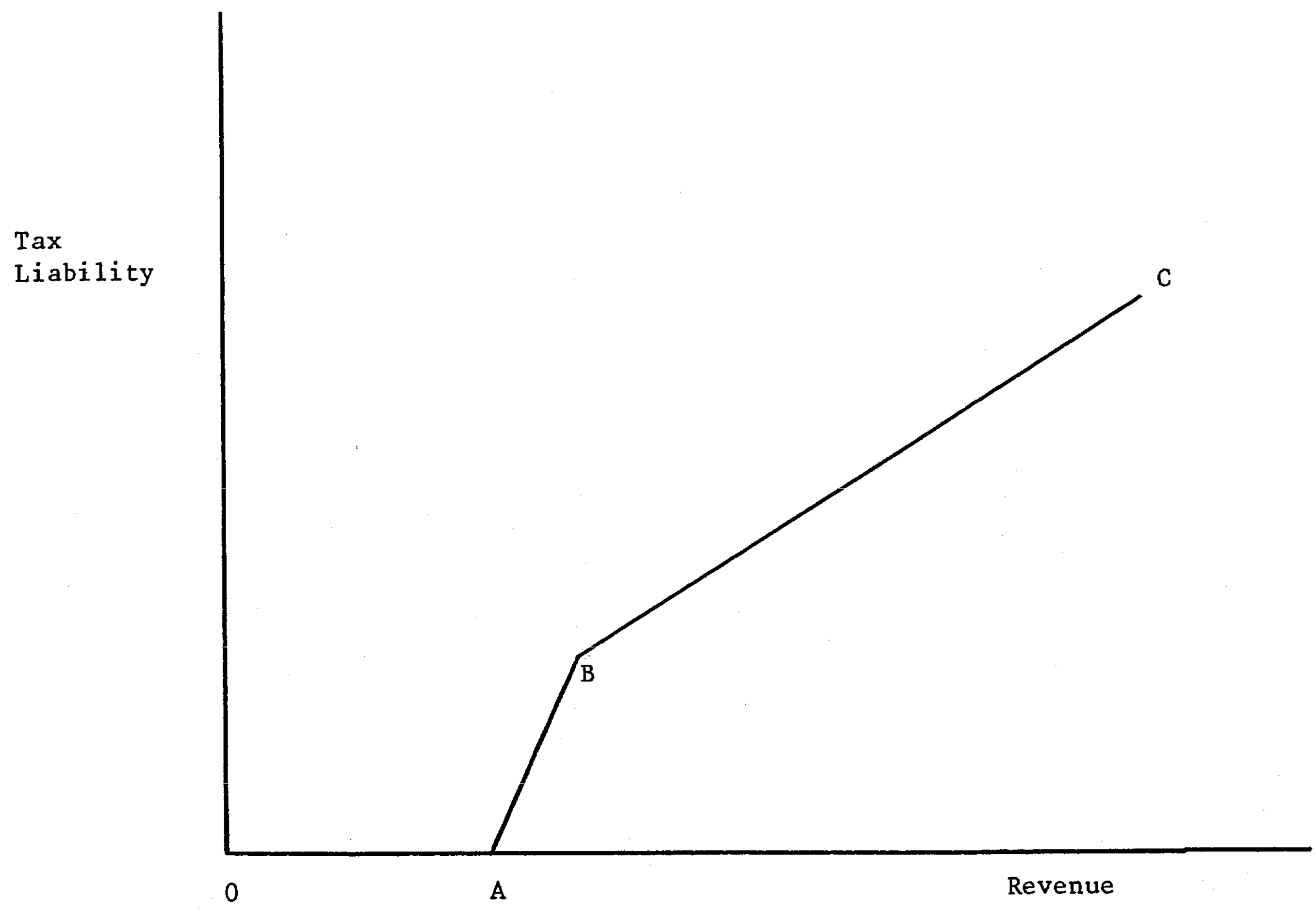
[1] In those cases where the firm was vastly over optimistic about the amount of oil contained in the tract, it can realize an immediate capital loss by selling the lease to someone else (if such transfers are allowed).

These effects of tax policy on the patterns of extraction <u>among</u> fields may be at least as significant as the effects on the intertemporal allocation of oil.

8. <u>The U.K. Petroleum Revenue Tax</u>

Companies operating oil and gas fields within the jurisdiction of the U.K. government are liable to the Petroleum Revenue Tax in addition to profits taxes and royalties. A striking feature of this tax is the misleading nature of its title; it is not, as one might suppose, similar to a royalty and levied on revenues. It is essentially an excess profits tax, and is levied on revenue net of certain operating and exploration costs, and net of royalty payments. Not all operating and exploration costs are allowable against tax -- thus interest on loans is not deductible (providing an incentive to hire plant rather than buy it with borrowed capital), nor is any expenditure depending wholly or partly on the quantity, value, proceeds or profits from oil won from the field. A further complication is that the incidence of the tax is to be limited so that liability to this tax in any year does not exceed 80% of the amount by which 'adjusted profits' exceed 30% of accumulated capital expenditure at the end of that year. Although the rationale of many of the details of the tax is unclear, this last provision makes it clear that it is basically an excess profits tax. The effect of its various provisions is that a graph depicting a petroleum revenue tax liability against gross revenue from an oil field might, for a typical structure of costs, look as in figure 2. Liability is zero below a certain revenue level: tax is then paid at a marginal rate that may start at 80% if the constraint that the tax should not exceed 80% of the excess adjusted of profits over a 30%



AB has slope 0.80 from equation

$$Tax = 0.8\ ((R - C) - 0.3K)$$

BC has slope 0.45 from equation

$$Tax = 0.45\ (R - C)$$

where R = revenue, C = current costs, K = accumulated investment.

Figure 2

return on capital is binding, and which decreases to 45% once revenue is sufficiently high that this does not bind.

What is peculiar about the structure of the Revenue Tax is that the marginal tax rate is zero for small revenues, very high for intermediate levels, and low (.45) for high levels. The effects of the tax depend critically then on what the pattern of extraction would have been in the absence of taxation. If the rate of extraction were constant, but price were increasing, so that revenue initially was below OA and eventually was above OA, clearly it will pay the firm to extract more oil early (when it is not taxed). In this case, the tax has the desired effect of encouraging the extraction of oil.

If, on the other hand, the pattern of extraction before tax was such that revenues always were strictly within the segments AB or BC, by the previous analysis,[1] the tax would have a conservationist effect, delaying extraction.

Finally, if revenues were in early years in AB and in later years in BC, the firm will postpone some extraction, since the marginal return to selling a unit of oil early is reduced by more than the marginal return to selling a unit later.

Thus it appears possible -- perhaps even likely -- that the imposition of such a tax, which was designed to encourage rapid development of these fields, may actually delay their development.

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[1] Although the analysis of this paper, including section 5, focuses on a tax which is universally applied, and is therefore not directly applicable to a tax(such as we are considering here)on only a small segment of the market, the conclusions are, nonetheless, still valid. For a small country, the rate of change of prices can be taken to be given exogenously. A firm within that country then will hold on to its oil so long as $\dot{p} - \dot{b} > r(p - b)$. A once and for all increase in the effective cost of extraction will thus delay extraction.

9. Monopoly

As we mentioned in the introduction, the biases due to taxation are certainly not the only ones in existence, nor are taxes usually applied in a perfectly functioning market. We cannot hope to discuss here all possible alternative imperfections, but one that clearly merits some review is the existence of monopoly in the resource market. What effect does this have on the initial pattern of resource-allocation? This question is fairly easily answered: it is still the case that the market will only be in equilibrium if the marginal return to the seller rises at the interest rate, but in this case of course the marginal return is marginal revenue minus marginal cost, so that with constant costs one has

$$\frac{\dot{MR}}{MR - b} = r \qquad (7)$$

where MR is marginal revenue. This is identical in form to the equivalent competitive equation, except that price is replaced by marginal revenue. More insight into the effect of monopoly is gained by noting that

$$MR = (1 + \frac{1}{\eta})\, p$$

where η is the price elasticity of demand. Letting $\gamma = 1 + 1/\eta$, (7) gives

$$\dot{\gamma}P + \dot{P}\gamma = r\gamma P - rb \qquad (8)$$

Let us look at the case when the demand elasticity is constant, so that $\dot{\gamma} = 0$. Then we have

$$\frac{\dot{P}}{P - b/\gamma} = r$$

as opposed to

$$\frac{\dot{P}}{P - b} = r$$

in the competitive case. Now, if the problem facing the monopolist is to be interesting, we need $\eta \leq -1$, in which case $0 \leq \gamma \leq 1$. The effect of monopoly is therefore as if extraction costs were raised from b to b/γ in a competitive situation -- this is of course the same as the effect of a sales tax in a competitive situation, and leads to a reduction in the rate of extraction. If the demand elasticity is not constant, then it is possible that the bias due to monopoly is in the opposite direction, though the most likely outcome seems still to be a reduction in the extraction rate.

Now adding a profits tax with constant depletion allowance at the rate α, we obtain

$$\dot{P}/(P - \frac{b(1 - \tau)}{(1 - \tau + \tau\alpha)\gamma}) = r$$

Hence if

$$\alpha = \frac{1 - \tau}{\tau} \cdot \frac{1 - \gamma}{\gamma}$$

the monopoly market with the tax distortion is identical to the competitive market. Other policies to correct to distortions introduced by the monopolist may similarly be devised.

10. Further Biases

We have focused in this paper on the effect of taxation on the intertemporal pattern of consumption of an exhaustible natural resource where there is a constant cost of extraction. Producers of oil had only a single decision to make: how much oil to extract each period. In fact, there are a number of other decisions which are important:

a) The total available supply of oil depends on exploratory activity, and this may be critically dependent on taxation. Any tax, as we noted earlier, that reduces the marginal return to oil will reduce the amount of exploratory activity. Since the present value of the marginal (net return) to a unit of, say, oil is constant, the effect on exploratory activity is determined simply by the effect on the net return to selling a unit of oil at the date of imposition of the tax. Thus, for instance, the depletion allowance which encourages excessive consumption of oil lowers the initial price. The profits tax, in conjunction with the oil depletion allowance, unambiguously reduces the net return to the producer; but with immediate write off of exploration expenses, whether exploratory activity is reduced or increased depends simply on the effect on $p(1 + \frac{\alpha\tau}{1 - \tau})$, where α is the depletion rate and τ is the tax rate. For any particular demand function we can, of course, calculate precisely whether exploratory activity is encouraged or discouraged.

b) The analysis so far has assumed that extraction occurs at a moment of time from any well. In fact, the "speed" of extraction is critical both in determining the total amount of oil that can be economically extracted from a well, and, of course, in determining the present value of the returns from the well. Depletion allowances may, by encouraging faster depletion, actually reduce the total amount of recoverable oil.

c) There are other important choices of technique in extraction, and these too may well be effected by taxation. In the case of most extractive resources, there are significant fixed costs. Firms may face trade offs between developing one large mine now, or developing a series of mines sequentially. These choices -- like the choice of any capital expenditure -- will be effected critically not only by the aspects of taxation we have discussed so far, but also by the provisions for depreciation of these capital expenditures. Since the output of any particular mine is likely to be determined by these "capacity" decisions, the short run effects (with fixed capacity) and the long-run effects (with variable capacity) of taxation on extractive resource industries may be markedly different. (Our analysis can be viewed as focusing on the long run.) (See M. Gaffney (1967) for a more extended discussion of this issue.)

d) In section 7 we mentioned briefly the effect of taxation on the pattern of extraction of oil among different wells or fields.

It is apparent that at the present time the pattern of extraction of oil does not conform to the dictates of economic efficiency: wells with high extraction costs are being operated simultaneously with low extraction costs. The social loss (calculated on a world-wide basis) from this is probably of an order of magnitude greater than the loss associated with the intertemporal distortions we have discussed here.[1] The extent to which they are due to tax policy remains, however, a moot point.

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[1] See Stiglitz (1975b).

11. Conclusions

Assume the government wishes, for one reason or the other, to have a pattern of resource allocation $R^*(t)$, with an associated set of consumer prices $p^*(t)$ ($p^*(t)$ is assumed continuous and differentiable). We can now see how the government could use tax policy to attain precisely this pattern. Although in fact a variety of instruments could be employed, all that is required is a tax on profits and a depletion allowance (the tax rates may have to be negative) such that

$$\frac{d \ln p^*[1 - \tau + \alpha\tau] - b(1 - \tau)}{dt} = r$$

i.e.

$$\dot{p}^*(t) = r \left[p^* - \frac{b(1 - \tau)}{1 - \tau + \alpha\tau}\right] + \frac{p(\dot{\tau}(1 - \alpha) - \dot{\alpha}\tau) - b\dot{\tau}}{1 - \tau \quad (1 - \alpha)} \qquad (9)$$

And $\{\alpha(t), \tau(t)\}$ satisfying (9) will generate the desired intertemporal allocation of resources. For instance, if α is set equal to a constant (9) provides a differential equation for τ. Tax policy can clearly be used as an instrument for changing the intertemporal pattern of resource allocation.

On the other hand, it is not obvious that the set of taxes presently imposed are designed with any clear view of what the desired pattern of resource allocation might look like. Indeed, it seems apparent that the effects are often contradictory to the announced intent of the policy. Moreover, various policies seem to have different effects.

A profits tax has no effect (if the rate of taxation remains unchanged) if interest income is tax exempt, but slows that rate of extraction if it is not.

A depletion allowance at a constant rate increases the rate of extraction, and its gradual removal increases it still further. A sales tax has precisely the opposite effects.

A capital gains tax -- with a loss offset provision for capital losses -- will tend both to lead to faster rates of extraction and to inefficient patterns of extraction among different wells and fields.

Over the past fifty years, there have been significant increases in the rate of taxation of profits, on sales of oil, and a gradual decrease in the depletion allowance. All of these changes are of the kind that if they were anticipated -- or if they are expected to continue -- lead to excessively fast exploitation of natural resources. On the other hand, at the present time, sales taxes on oil typically exceed the depletion allowance, so that -- ignoring for the moment the effects of the capital gains provisions -- if firms expect rates of taxation to remain relatively unchanged, the present tax structure encourages excessive conservationism. Thus, the effects of tax structure on the patterns of extraction are critically dependent on expectations concerning future taxation. Whether in fact current tax policies have lead to excessive conservationism or not is thus a moot question.

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