THE WELFARE COST OF RESOURCE TAXATION

by

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1. Introduction

The appropriate tax treatment of extractive resources has been extensively and heatedly debated over the last 30 years. Much of the discussion has centered on the wisdom of maintaining the many special tax provisions which affect resource industries, such as the percentage depletion allowance, expensing for intangible drilling costs, severance taxes, and the crude oil windfall profits tax.[1] The arguments are not over trivial amounts: the windfall profits tax alone was scheduled to raise $227.7 billion in net revenues in the 1980s.[2] The magnitude of the revenues involved suggest that efficiency considerations are significant. For this reason, the welfare cost of such taxes should be analyzed, especially since there are special features to resource production.

The central feature of extractive resources for the purposes of this analysis is their exhaustibility — that is, fixed (although possibly unknown) supply at a given cost of exploration and extraction. Among the implications of exhaustibility are that the value of the resource is greater than the cost of extraction -- along both the competitive equilibrium and socially optimal time paths of extraction — and that intertemporal choice is an essential part of the production decision.[3]

The theoretical literature on the taxation of exhaustible resources notes that the scarcity rent — the difference between the value and cost of production — can be taxed without loss in allocative efficiency.[4] Levying such a tax requires either the ability to tax directly the owners of the mineral rights, or an exact knowledge of the cost structure of the industry and the freedom to change tax rates over time. In practice, these requirements may be difficult to satisfy, at least if private ownership of the mineral is maintained.[5]

Since many countries, including the U.S., have taxes which alter the intertemporal extraction path, the effect of these taxes should be considered. Various papers address this point, but stop after determining the effect of a particular tax on the time path of production. For example, Dasgupta and Heal (1979) note that a constant-rate sales tax or a profits tax result in slower initial extraction rates than the undistorted equilibrium, while the percentage depletion allowance results in more rapid usage.[6]

The omission of any welfare cost calculation from the analysis is serious. Most other taxes cause distortions. The welfare cost for resource taxes per dollar of revenue should be compared with alternative means of raising revenue.[7] Should exhaustible resources be taxed more or less heavily than conventional commodities?

To address this question, it will be shown that the principles of applied welfare economics elucidated by Harberger (1971) can be extended to exhaustible resource taxation. Earlier efforts, such as Arrow and Kalt (1979), ignored the intertemporal decisions facing producers. Despite the complexity of the producer's optimization problem, the welfare cost of a distortionary tax can be expressed in a simple form.

The welfare cost of a tax on resource production in a single period, in the absence of other distortions, is described in Section 2. The welfare cost of multi-period taxes is considered in Section 3. In Section 4, a number of complications, such as capital taxes, are discussed.

The analysis suggests that taxes on exhaustible resources have relatively low welfare costs, even if they distort the time path of production, so long as they are permanent. Section 5 reviews these conclusions and discusses the possible extensions.

2. Welfare Cost of a Temporary Tax

In this section, the welfare cost of a one-period tax on the production of an exhaustible resource is analyzed. As is usual in the public finance literature, the welfare cost of a tax is the loss in utility from a tax over and above that which would have occured if the same revenue had been raised in a lump-sum manner.

The principal difficulty in analyzing the welfare cost of exhaustible resource taxation is that the value of the resource to consumers and society is greater than the cost of exploration and extraction at the margin. This would seem to violate one of the three basic postulates of applied welfare economics: "the competitive supply price for a given unit measures the value of that unit to the supplier."[8] In fact, the postulate still holds for resources, as demonstrated below.

The difference between price and cost is the scarcity rent which reflects the opportunity cost of producing the resource today, rather than in the future. This opportunity cost is a cost to society, as well as to resource owners. That is the essence of theorems which prove that the socially optimal time path of extraction is the same as that chosen in competitive equilibrium, so long as the social discount rate is the same as the private rate, property rights are secure, and uncertainty is absent.[9]

The conventional supply curve for an exhaustible resource measures, for competitive producers, the opportunity cost of the production. Applying the three basic postulates, the welfare cost of a <u>one-period</u> tax can be straightforwardly found. In the absence of any other distortions in the economy, a tax T_i^* on the exhaustible resource j in period t leads to the change in welfare:

$$\Delta W = \int_{T_j=0}^{T_j^*} e^{-rt} T_j \frac{\partial X_t^j}{\partial T_j} dT_j, \tag{1}$$

where r is the discount rate (assumed constant for notational convenience) and X_t^j is the quantity produced of resource j in period t.[10] That is, the welfare cost is the standard triangle.

It is true that the imposition of the tax will cause an outward shift in the supply of the resource in future periods, as producers adjust to a new equilibrium path. Under the assumption of no other distortions, the welfare change is unaffected by such responses, as with any other demand or supply shifts. What matters on the supply side is the general equilibrium response of production in period t to the imposition of the tax.

It is important to note that the welfare cost in equation (1) is <u>not</u> the difference between the value and the extraction (or even extraction plus exploration) cost of the lost production in period t. Typically, this lost production will not be lost forever. Indeed, under certain assumptions, cumulative production of the exhaustible resource would be unaffected by the tax.

At least a portion of the lost scarcity rent will be recovered, from the perspective of both producers in period t and society. Due to the pecuniary externality created by the shifting of production, the scarcity rent of producers in other periods will generally fall. It is possible for the present value of the scarcity rent to all resource owners to fall by more than the full amount of the tax.

These results are formalized in the following theorems. It is assumed that producers are competitive and maximize the present value of profits on the resource. Costs for any unit are known, occur in the period of production and are independent of the period of production and the pattern of extraction. Demand in any period is a nonincreasing, continuous function of the price in that period only, though it need not be stationary. These assumptions shall be maintained in all theorems in the next two sections. The tax is levied only on the resource produced in period t.

Theorem 1: Consider the resource produced in period t prior to the tax, X_t. Let c_t^{max} be the highest cost of production of any units in X_t. If price, $p_{t'}$ is greater than c_t^{max} for all $t' > t$, or if $\sum_{t'=t+1}^{\infty} X_{t'} > X_t$, then all of the resource which would have been produced in period t in the absence of the tax will be produced eventually despite the tax.

Proof: If costs are certain, producers can choose which period to produce, and extraction costs do not depend on time or the extraction pattern, the price of the resource will be rising over time whenever production occurs and the lowest cost units will be produced first.[11] If $p_{t'}$ is greater than c_t^{max} along the original production path for all $t' > t$, all of the original producers in period t could make positive profits even if demand in period t were 0, by the assumption that demand is continuous in every period and independent over time.

The tax will not cause any resource production to be shifted from periods before t to periods after t, nor will it increase cumulative resource production. Since any production originally scheduled for periods after t have costs no less than c_t^{max}, producers in period t cannot be undersold. Therefore, they will eventually produce, even if the tax stops production in period t.

A similar argument applies whenever cumulative production originally scheduled after period t is greater than production in period t. All of the period t producers could make positive profits by postponing production, so that, regardless of the tax, they will eventually produce. Q.E.D.

Theorem 1 states that producers originally scheduled to produce in period t will eventually produce, even with the tax. It is still possible that some high-cost production (originally planned for sometime after t) will be lost once the tax is imposed. The conditions in Theorem 2 are sufficient to rule out this possibility.

Theorem 2: If $X_{t'} = 0$ for all $t' > T$, with $X_T > 0$ and T finite, and if $D(0) = p^*$ for all $t' > T$ along the original production path, then cumulative production will be unaffected.

Proof: These conditions would hold in equilibrium if, for example, there was a backstop technology which was a perfect substitute in elastic supply. Under these conditions, all of the resource with cost less than or equal to p^* will be produced without the tax, since it will be profitable and the producers are competitive. With the tax, all of the resource scheduled for production could be profitably produced even if production in period t were stopped. By the continuity of demand, all production with cost less than p^* will eventually be profitable to produce. Since the tax would not make any other production profitable, cumulative production would be the same with or without the tax. Q.E.D.

The following theorem shows that it is possible for present value of the total scarcity rent to fall by more than the full amount of the tax.

Theorem 3: If extraction costs are zero, and demand is stationary with constant elasticity greater than one, then the present value of the scarcity rent will fall by more than the full amount of the tax.

Proof: Under these conditions, the competitive production path is the same as the unique production path of the monopolist.[12] Since the price set by the monopolist maximizes the present value of the scarcity rent, any change in the price path will lower the revenue collected. Yet the imposition of a tax in period t will change the production and price paths. Total receipts including taxes paid, will fall. Therefore, the present value of the scarcity rent fall by more than the amount of the tax. Q.E.D.

The welfare cost of a single-period production tax is the difference between the value of lost production in that period and the value of the factors used in the production in their best alternative use. In the case of the exhaustible resource, that alternative use is probably production at some other time.

3. Welfare Cost of a Permanent Tax

If a tax is levied on resource production in more than one period, equation (1) needs to be modified even if there are no other distortions. More than one market is distorted, since resource markets at different dates are affected by the tax.

Consider a tax imposed in period t on production of an exhaustible resource with a tax already having been imposed on the rsource in some other period. Again applying the three postulates, this case is equivalent to a tax on any good in the presence of preexisting tax distortions in other markets. The notation of Harberger (1971) needs to be modified only slightly. The change in welfare is:

$$\Delta W = \int_{T_{t=0}}^{T_t^*} e^{-rt}\, T_t \frac{\partial X_t}{\partial T_t}\, dT_t + \int_{T_t=0}^{T_t^*} \sum_{t' \neq t} e^{-rt'}\, T_{t'} \frac{\partial X_{t'}}{\partial T_t}\, dT_t \qquad (2)$$

where $T_{t'}$ is the tax imposed on the resource in period t'. As pointed out by Harberger,[13] this is equal to the standard welfare cost triangle, which reduces welfare, plus, when the $T_{t'}$ constant, the term $\sum_{t' \neq t} T_{t'} \Delta X_{t'}$ where $\Delta X_{t'}$ is the change in the equilibrium quantity of $X_{t'}$ caused by the tax T_t.

The general equilibrium welfare cost of a tax in period t will be larger or smaller than the welfare cost triangle according to whether $\Delta X_{t'}$ is negative or positive. Fortunately, in the case of an exhaustible resource, the sign is usually known. At least when demand at different times is independent, imposition of a tax in period t will incrase production at other times and, therefore, reduce the distortion caused by the taxes in other periods. The welfare cost of imposing a tax on an exhaustible resource, when the only other distortions are taxes in other periods, will be smaller than the conventional triangle.

The following theorem formalizes this result. Once again, costs are assumed to be known, independent of time and extraction patterns, and incurred when production occurs. Quantity demanded is a nonincreasing, continuous function of current price only, though it need not be stationary. Producers can choose which period to produce.

<u>Theorem 4</u>: (a) The welfare cost of taxing exhaustible resource production in period t is less than or equal to the expression in equation (1), that is:

$$\Delta W > \int_{T_t=0}^{T_t^*} e^{-rt}\, T_t \frac{\partial X_t}{\partial T_t}\, dT_t \qquad (3)$$

whenever the only other distortions in the economy are taxes on resource production in other periods.

(b) The inequality in equation (3) is strict if the resource has a constant extraction cost and demand is strictly decreasing in all periods, and if $X_t > 0$ and $X_{t'} > 0$ for some t' which had a tax on the resource.

<u>Proof</u>: The proof for part (a) requires showing that imposition of a tax in period t will not decrease production in any other period. The tax shifts

demand downward in period t from the point of view of the producer and, by the assumption of independence of demand, no other demand curve is shifted. Production in period t will not increase, since the relative attractiveness of producing then has been decreased. Production will not decrease in any other period since the present value of the scarcity rent on the total stock cannot increase. A reduction in the quantity produced in any period except t would imply that producers had a more favorable opportunity in some other period. Since no demand curves have shifted up and demand in period $t' \neq t$ is unchanged, this is not possible. Since production will not decrease in any such period t', all of the $\Delta X_{t'}$ are nonnegative. Therefore, the second term in equation (2) is nonnegative and equation (3) follows.

If extraction costs are identical, as assumed in part (b), and producers are competitive, the present value of the scarcity rent must be the same in all periods in which production occurs. If demand is a decreasing function of price in period t, imposition of the tax will reduce the price received by producers at the production prevailing before the tax. Production in period t will unambiguously decrease. Since demand in other periods is not perfectly elastic, the price received by at least some producers must fall. If the scarcity rent is reduced for some producers, it must be lower for all of them in equilibrium, if the extraction costs are the same. This means that price must fall in every period in which production occurs. If demand is continuous and decreasing, this can only happen if production increases in every period except t in which production previously took place. Since at least one such period had a preexisting tax distortion by assumption, at least one of the $\Delta X_{t'}$ must be strictly positive. Since, as argued above, all of the $\Delta X_{t'}$ are nonnegative, the second term of equation (2) is strictly positive.

Q.E.D.

The intuition behind Theorem 4 can be stated differently. There is a fundamental inelasticity associated with an exhaustible resource. While production will shift among different periods, the existence of the scarcity rent means that the elasticity of ultimate production of a particular unit is substantially less than the elasticity of its supply in any single period. A multi-period tax takes advantage of this ultimate inelasticity and captures more of the scarcity rent.

Theorem 4 has a number of policy implications. Holding the response to each individual tax constant, production taxes on an exhaustible resource in several periods have a lower welfare cost per dollar of revenue raised than similar taxes on unrelated markets. Moreover, adding additional periods of taxation increases the advantage over the same number of unrelated markets, *ceteris paribus*, since additional reductions in the distortions caused by taxes on resource production in other periods occur.

One way to think of a permanent tax on an exhaustible resource is to imagine a tax imposed on a single period t, then on some other period t', then in period t", and so on, until a tax is imposed in every period. Each of these taxes generates a welfare cost triangle similar to the first term in equation (2). Each tax, other than the first, generates rectangles similar to the second term of equation (2). In general, the size of these triangles and rectangles will depend on the order in which the taxes are imposed in the thought experiment, though the sum of their areas -- the total welfare cost of the permanent tax -- will be the same.

The important point is that the total welfare cost of a permanent tax will be less than the sum of the triangles in this thought experiment. By Theorem 4, all of the rectangles increase welfare.

A welfare cost calculation which was based on the supply response to one period changes in, for example, demand would be appropriate for a single period tax. It would overstate the welfare cost of a permanent tax. Such a calculation ignores the gains resulting from a reduction in the welfare cost caused by distortions in other periods. The elasticity of supply is greater for a one-period or temporary tax than it is for a permanent tax.

This suggests that, in the absence of any other evidence, exhaustible resources should be taxed more heavily than other commodities. Permanent taxes on exhaustible rsources will tend to have a lower welfare cost per dollar of additional revenue than equivalent taxes on commodities which had the same sum of triangles in similar thought experiments. The ideal permanent tax on resource production would, of course, be a first-best tax. Tax rates in different periods could be manipulated so as to cause no change in the production path. The importance of Theorem 4 is that, even if such a first-best tax is infeasible, the welfare cost of permanent resource production txes will tend to be lower than equivalent taxes. Permanent resource production taxes have some of the characteristics of a first-best tax.

Until now, it has been assumed that there are no other distortions in the economy. In the following section, this assumption is relaxed.

4. Welfare Cost of Resource Taxation When There Are Other Distortions

Conceptually, the analysis of the welfare cost of resource taxation in the presence of other distortions is no different than if the tax were on an ordinary commodity. Imposition of a resource tax causes an adjustment in the general equilibrium, shifting supply and demand curves in other markets, including those which are distorted. Those shifts which exacerbate the distortion increase the welfare cost, while those which mitigate distortions lower the cost.[14]

A particularly important set of distortions in the economy is caused by taxes on capital. Resource markets are connected with capital markets in interesting ways. Capital and many exhaustible resources, such as oil and natural gas, are factors of production, so demand for each is connected through the production function. Secondly, capital formation and resource production inherently involve intertemporal decisions.

The effect of a resource tax (as compared to a lump sum tax) on capital formation depends largely on whether capital and the resource are substitutes or complements. If they are substitutes, the marginal product of capital will rise (fall) in periods where resource use decreases (increases). If they are complements, the reverse is true.

Ignoring other indirect effects of the resource tax and, for the moment, intertemporal issues, the welfare cost of the resource tax will not be much different from that calculated in previous sections when cumulative resource production is unaffected. The shifting of resource production among periods will increase the marginal product of capital in some periods and reduce it in others, with corresponding impact on savings in the preceding period. With cumulative resource production unchanged and a constant tax on capital, the rectangles of welfare gain and loss due to these shifts in saving will approximately cancel out.

If cumulative resource production is reduced, the sum of the rectangles due to the shifts in savings will probably be negative (positive) if the resource and capital are complements (substitutes). In the case they are complements, there will be more periods when saving is reduced than increased, and so the distortion caused by the capital tax will probably be worse. In this case, the welfare cost calculated using equation (2) would be an underestimate.

If the resource tax is unexpected, the adjustments to equation (2) as a result of the capital tax depend on the effect of the resource tax on the timing, as well as the level, of resource extraction. Timing is important since the initial capital stock cannot be adjusted in response to the changes in the marginal product of capital.

For example, constant-rate sales tax postpones production of the exhaustible resource. If the resource and capital are complements (substitutes), this will increase (decrease) the marginal product of capital in the future. Saving will tend to increase (decrease), and the distortion of the capital tax will be reduced (increased). The welfare cost calculated using equation (2) will need to be reduced (increased), even if cumulative production is unaffected.

5. Conclusions

The three basic postulates of applied welfare economics, when applied to the problem of exhaustible resources, yield some surprising insights. Despite the complicated intertemporal adjustments which it induces, the welfare cost of a one-period tax on resource production can be calculated knowing only the elasticity of resource supply and demand in that period. It will be less than the difference between price and extraction cost on the lost production, since the production will not be lost forever. The same thing is true for temporary price controls. Resource producers may bear more than 100% of the burden of the tax, though resource producers in a particular period will not.

A permanent tax on an exhaustible resource will have a smaller welfare loss per dollar of revenue raised than a temporary tax, since the elasticity of supply is smaller with the permanent tax in general equilibrium. Using single-period supply and demand elasticities will tend to overestimate the welfare cost of a permanent tax.

In the presence of capital taxes, little modification needs to be made for a resource tax which is anticipated and causes no loss in cumulative production. When capital taxes must be taken into account, the sign of the derivative of the marginal product of capital with respect to the level of the resource is critically important. For an unexpected resource tax, the effect on the timing of resource production is also significant.

The most important policy implication relates to whether exhaustible resources should be taxed more or less heavily than other goods. The answer for a one-period tax depends purely on the relative magnitudes of the supply and demand elasticities for the resource and for other goods. The interaction among resource supply curves in different periods causes a permanent tax on resource production, even if it is distortionary, to have some of the characteristics of a first-best tax. This leads to a presumption that the permanent tax on resource production has a smaller welfare cost per dollar of revenue than taxes on ordinary commodities. This presumption needs to be verified with careful empirical analysis of resource supply and demand elasticities.

Since 1970, resources, which formerly were taxed much more lightly than other industries, have faced an increasing tax burden, with the partial elimination of the percentage depletion allowance, the increase in severance taxes, and the imposition of the crude oil windfall profits tax.[15] The analysis in this paper indicates that this may have been a move in the right direction.

Footnotes

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[1]The Treasury Department [1984] proposed eliminating expensing for intangible drilling costs, and percentage depletion, and rapidly phasing out the windfall profits tax as part of its tax reform proposal. After this generated an outcry, President Reagan's plan retreated in all three areas. For an earlier debate, see Harberger [1955], McDonald [1961 and 1964], and Steiner [1964].

[2]The windfall profits tax is scheduled to phase out over a 33-month period beginning in January 1988 or in the month after cumulative revenues reach $227.3 billion, whichever is later. In any event, the phaseout will begin no later than January 1991 (Arthur Anderson [1980]).

[3]Among many proofs of this, see Stiglitz [1974a,b] and Sweeney [1977].

[4]See Dasguptz and Heal [1979], especially Ch. 12.

[5]Even if the government owns the resource it may not capture the full resource rent when there is uncertainty (see Robinson [1984]).

[6]See also Sweeney [1977], Dasguptz, Heal, and Stiglitz [1980], and Jacobsen [1979].

[7]Stiglitz [1975] attempts a calculation of the optimal tax, on oil, in a static model with resource owners earning rents. Wright [1977] shows that Stigler made both calculation and conceptual errors. Gamponia and Mendolsohn [1985] analyze a property tax on a resource using simulation techniques,

rather than theory. Boskin and Robinson [1985] consider optimal energy taxation, but focus on static issues.

[8]Harberger [1971], p. 786.

[9]See Sweeney [1977].

[10]This is similar to Harberger [1971], equ. 1.7.

[11]See Griffin and Steele [1980] and Dasgupta and Heal [1979].

[12]See Stiglitz [1976] and Weinstein and Zeckhauser [1975].

[13]Harberger [1971], p. 790.

[14]Harberger [1971] uses an elegant expression

$$\Delta W = \int_{Z=0}^{Z^*} \sum_i D_i(Z) \frac{\partial X_i}{\partial Z} dZ$$

where D_i represents the excess of marginal social benefit over marginal social cost and Z is the policy variable.

[15]Fullerton and Henderson [1983] and Auerbach [1983] find the effective marginal tax rate on investment in plant and equipment in energy industries to be approximately the same as in other sectors. Gravelle [1982], on the other hand, finds a much lower effective marginal tax rate on energy. The strong assumptions used make all of these studies, useful as they are, open to question.

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