Rent taxation for nonrenewable resources
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Rent Taxation for Nonrenewable Resources

A Critical Review of the Literature

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Didrik Lund

Department of Economics, University of Oslo, Norway

diderik.lund@econ.uio.no

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Abstract  Ideally, the literature on resource rent taxation builds on economic theory, includes uncertainty in models, explains important real-world phenomena, and leads to clear policy recommendations. Much of the literature falls short of the ideal. The traditional approach, introducing taxes in Hotelling models, has problems with uncertainty, and is largely irrelevant for explaining the world and recommending policy. The policy-oriented literature often goes to great lengths in describing aspects of different tax systems, allowing for various comparisons, but typically with little theoretical basis for making the comparison. The literature which recommends cash bonus bidding alone has not gained widespread following outside the U.S.A., but combinations of bidding and taxes have many proponents. Implementation is difficult, however. Other approaches suffer from lack of a model for resource price processes. Few contributions attempt to point to an optimal tax rate, and if so, based on very restrictive assumptions.
1 INTRODUCTION

In many countries extraction of nonrenewable natural resources is important, also as source of government revenue. This is true in different countries for petroleum, coal, and metals and other hard-rock minerals like diamonds. Recent overviews, Baunsgaard (2001) and Otto et al. (2006), show world-wide use of various forms of taxes specific to these sectors.

In order to minimize the need for distortionary taxes, economists have recommended rent taxes, which are supposed to be neutral. A combination of factors makes the design of these taxes or alternative arrangements for government revenue very challenging. There can be large rents in periods when resource prices are high, and thus a strong public demand for government revenue. There is high uncertainty in prices and geology, and technology is often owned by big multinationals. This raises issues about attitudes to risk and asymmetries of information, which are exacerbated by high tax rates. This paper is a literature review, concentrating on the literature since 1975.

The two next subsections delineate the topic and introduce some theories of companies’ behavior. The subsequent four sections present major strands of the literature. Section 2 considers models in the Hotelling tradition. The question is how taxes affect the equilibrium price path for a nonrenewable resource. A problem for policy relevance is that taxes are implicitly assumed to be world-wide. Section 3 focuses on studies directed at policy reforms. Some of these have been highly influential, in spite of some weaknesses which are pointed out. Section 4 discusses various approaches to the analysis of tax distortions to companies’ decisions. Section 5 shows how auctions have been promoted as alternative to taxation, and possible advantages for combining the two. Section 6 contains a number of miscellaneous topics. Other important topics could have been included, but there is a space limitation. Section 7 offers concluding remarks.
1.1 Delineation of the Topic

Governments have revenues from natural resource activities in various legal and economic forms. A company extracting a nonrenewable resource may have ownership of the resource, or may obtain licence to exploit it. The company’s resource extraction is subject to taxation, perhaps together with a larger part or the whole company. “Taxation” means that payments depend on the realized outcome of the activity. If the complete payment is determined independently of realized outcome, it is not considered as taxation. A fixed fee may be set by the government, negotiated with companies, or determined through auction. This review only cover parts of the literature on fixed fee systems.

Besides taxes and fixed fees, there is a third alternative, equity participation. It is difficult to draw the line between taxation and forms of government involvement closer to equity participation. One can imagine production sharing agreements in which the government has some direct influence on decisions of the operator, but not the same general rights as owners. The analytical distinction is that under taxation, the government only determines tax rules (tax base definitions and tax rates), while companies make operating decisions knowing that these will influence the amount of taxes.

Governments also regulate many aspects of the activity, which has implications for the practical interest in analysis of taxation. If all companies’ choices are severely restricted, there may be little actual influence from distortionary taxes. In practice it seems that some choices are less restricted than others, but this varies greatly between countries and types of resources. An important reason to rely on private-sector companies is that they have expertise which they apply in their own self-interest. Thus they must be left with important choices to make, which gives room for tax distortions.

“Royalty” denotes taxes on gross production value. Parts of the literature uses royalty more generally to include also net profits (or rent) taxes. This may be a matter of definition only,
but the difference between taxes and royalties has historical roots related to their justification. According to Watkins (2001), “One dictionary definition of a tax is a ‘contribution levied on persons, property, or business for support of government.’ Although royalties may be used to support government, that is not their raison d’être. Rather, royalties derive from ownership of resources by the Crown. Thus, a functional distinction can be made between royalties and general tax revenues. In this light, the principles governing taxation do not apply in equal measure to royalty incomes” (p. 29). Philosophical discussions on justifying taxes or royalties are omitted here. This may have economic implications, however, for instance when the U.S. decides on what taxes and royalties are eligible for foreign tax credit.

For analytical simplicity it is convenient to assume that economies are open with a world market for extracted (and possibly refined) units of the resource. This allows a distinction between rent taxes and excise taxes. A rent tax is a tax levied on rent realized when the resource is sold at the world market price. Excise taxes, not a topic here, come on top of the world market price, adding to the consumer price.

1.2 Alternative Models of the Behavior of Companies

In order to predict effects on behavior of companies, one needs assumptions about how companies make their decisions. Different studies use different assumptions. This subsection will only highlight major differences which anyone who study the topic should be aware of. We first look at two alternative sets of assumptions regarding risk. Then we mention another alternative assumption, related to the volume of rents.

Some studies assume risk aversion on part of companies. When formalized, the assumption is often that companies maximize expected utility in the sense of von Neumann & Morgenstern (1947) (vN-M hereafter), with a concave utility function with profits as the argument. Other types of preferences with aversion to risk are found in studies of taxation by, e.g., Domar & Musgrave
(1944) and sections II–V of Emerson & Garnaut (1984). There is often no consideration of diversification possibilities for the company itself or for its shareholders. Variance or some other measure of dispersion of profits is sometimes taken as measure of risk. If the company diversified, the covariance between one project and the rest of its portfolio would take over as risk measure. If shareholders diversify, we move to the next paragraph. But there is also the possibility that managers act in their risk averse own self interest, neglecting preferences of shareholders.

Alternatively, companies maximize market value, supposedly in the interest of shareholders. The market value is additive, in the sense that the value of a linear combination of assets is equal to the same linear combination of separate values of those assets. This follows from theories developed since around 1960, such as the Arrow-Debreu model of complete markets (Arrow 1953, Debreu 1959), or various models in financial economics, starting with the Capital Asset Pricing Model of Sharpe (1964), Lintner (1965), and Mossin (1966). Value additivity implies that variance cannot be a risk measure for each part of a portfolio, while covariance can.

For the theoretical study of taxation of companies, and for resource extraction in particular (high tax rates, high risk), the implications of making one of these assumptions are far reaching. Since companies differ, and none of the models of financial economics is established as the final truth about financial markets or decision making, there are arguments for both types of models.

Finally in this section, we notice an assumption which has received some attention recently. Osmundsen (2005) assumes that oil companies, in order to start a project, require some minimum volume of rent, sometimes called “materiality.” Again, this is an assumption with far-reaching implications. Any rent tax, even with a low tax rate, will then cause some projects to move from being acceptable to unacceptable. For any project, even with a high rent, there could be a rent tax at a rate high enough to move it from acceptable to unacceptable.
2 EQUILIBRIUM MODELS

Since Hotelling (1931) the analysis of economics of nonrenewable natural resources has been based on dynamic equilibrium models of the market for the resource. These are typically partial-equilibrium models with exogenous interest rates. The value of an unextracted unit must rise at the rate of interest. Herfindahl (1967) extends the model to include deposits with different costs, which determines the sequence in which they will be extracted.

Introduction of taxes in a version of the Hotelling (1931) model is discussed in chapter 12 of the otherwise influential text book by Dasgupta & Heal (1979). Most of the analysis considers a model assuming continuous extraction from each deposit. The question is how different taxes distort the market solution. Some neutrality results are derived. A final section considers taxation as a means to correct for tragedy-of-the-commons problems. The main model in the chapter is of a closed economy, or of world-wide taxation. The question raised is how the resource price path is affected when all extraction is subject to the same type of tax with the same rate. This is hardly relevant as policy advice. A government will either consider its country to be a price taker, or at most have some limited market power.

Almost all subsequent theoretical studies of resource taxation have assumed exogenous prices. Virmani (1985, 1986), writing for the World Bank, is among the few to discuss the issue, opting for exogenous prices. Even the World Bank did not have ambitions to affect world resource prices through its advice on taxation. The oil price is endogenous in a model by Lindholt (2008) on petroleum taxes in Norway. With the modest market share, it is hard to see why taxation in that country should affect prices to an extent which justifies that complication in the model.

Few studies have analyzed resource taxation in an intertemporal general equilibrium model, in which the interest rate is also endogenous. Groth & Schou (2007) have a general growth model for a closed economy, which encompasses both endogenous and exogenous growth, with both produced and natural capital and a possible externality from resource use, such as global
warming. The resource use goes asymptotically to zero, with all of the resource being used, in infinite time. Restricting attention to balanced growth paths, the study shows that the resource use will decline exponentially, with the decline rate possibly affected by taxation. The model cannot analyze distortions from labor income taxation, as there is no labor-leisure choice. But the model tells something about the effects on growth of alternative taxes on the two types of capital. Of course, it suffers from the unrealistic feature that the same taxes are applied on all natural capital, world-wide. The main result on resource taxation is that a tax on profits on resource-extracting companies leads to too little conservation of the resource, thus impeding growth.

As pointed out by Boadway et al. (2008, p. 14) there is evidence (Krautkraemer, 1998) against the empirical relevance of Hotelling models, which would also include Groth & Schou (2007). Another problem with existing equilibrium models is the absence of uncertainty. Unfortunately, there is so far no established model of a dynamic equilibrium under uncertainty in such a market, to extend the Hotelling-Herfindahl tradition. We shall see below that at best, taxation has been treated with an exogenous price process, although not necessarily a credible one. Lund (1993) points out why the geometric Browninan motion with drift (GBMD) is hardly an equilibrium price process. GBMD is nevertheless assumed in three studies to be discussed below, Ball & Bowers (1983), Lund (1992), and Zhang (1997).

3 COMPARING TAX SYSTEMS, SUGGESTING TAX REFORMS

The basic problem for a single country trying to collect resource rent via taxation is that a higher tax rate in one sector is likely to distort decisions by companies. One might simply set a higher tax rate for a corporate income tax (CIT) in this sector. But the wedge between rates of return before and after tax increases with the tax rate. In a closed economy, this will be counteracted if interest income and all corporate income is subject to a tax at the same rate; the Johansson-
Samuelson Theorem (Sinn 1987, p. 119). But this does not help if one sector has a higher tax rate than the rest of the economy, or in open economies. A higher tax rate with an unmodified tax base will mean that projects (or high-cost resource units within projects) which would be seen as profitable under a lower tax, can be rejected under the higher tax.

A royalty also distorts decisions. Without cost deductions it makes resource units with high costs unprofitable. In actual tax systems there may be many complicating features, including taxes and deductions at several levels. A general illustration of the high potential for distortions is that a marginal decision is distorted by the ratio \((1 - t_y)/(1 - t_c)\), where \(t_y\) is the marginal tax rate on income and \(t_c\) is the marginal tax (deduction) rate on costs. These are not statutory rates, but effective rates in an expected, risk-adjusted present value sense. Clearly, the higher the rates, the more sensitive will this ratio be to small differences in the rates. Thus there has been interest in economic analyses of how to optimally tax resource rent.

The seminal article for this part of the literature is Garnaut & Clunies Ross (1975), proposing a tax scheme named the Resource Rent Tax (RRT). The purpose was to define a tax base close to true rent. The RRT intends to give a deduction equal in present value to the investment itself, typically exceeding most CIT systems’ depreciation allowance. A generalization of the idea is found in Boadway & Bruce (1984). The investment, and any additional yearly net loss (which often occur for several years in large extraction projects), are carried forward for later deduction, with interest accumulation, as soon as revenues allow. Under the assumption that the tax base in subsequent years will be sufficiently high to allow complete, effective deduction, this can ensure that only the rent is taxed.

Authorities must determine an interest rate for the accumulation. The intention is that companies are indifferent between receiving the refund immediately or through deductions in subsequent years. Garnaut & Clunies Ross (1975, 1979; 1983 ch. 4) acknowledge that implementation will suffer under information asymmetry. They suggest that the correct rate to use will be companies’
required rate of return. They state that there will be a risk premium included, but have no model or precise discussion of how this is determined. Subsequent literature (Mayo, 1979, Ball & Bowers, 1983, Lund, 1992) focuses on the possibility that income stream in later years may be insufficient to allow for an effective deduction. The original RRT proposal and most practical implementations do not offer a payout if the income stream is too small. Garnaut & Clunies Ross (1979, p. 196) recognize that there may be a problem due to asymmetric treatment of profits and losses.

Inability to decide on the correct rate for interest accumulation leads to a suggestion to use two or three different rates. If, and as soon as, a rate of return above a lower threshold is realized, the company starts paying RRT at a relatively low rate. If a rate of return above a higher threshold is realized, the company starts paying at a higher rate. Garnaut & Clunies Ross (1975) give an example with a 50 percent tax above 10 percent rate of return, and an additional 25 percent tax above 20 percent rate of return. They give several reasons for applying more than one rate. In addition to ignorance about actual required rates of return, and the possibility that these differ between projects, there is a sketch of an argument (p. 280) that risk aversion makes progressivity desirable. A different argument in Boadway & Keen (2008, p. 45) is that “progressive rate schedules may be more robust against political pressures in the event of high return outcomes than are proportional schemes.”

While risk aversion is in the title of Garnaut & Clunies Ross (1975), there is no formal definition of it. There is an informal description of a non-linear objective function (p. 273), similar to risk aversion in a vN-M setting, but no formal derivation of results. This vagueness conceals some problems. Their arguments in this connection can be contrasted with two alternative approaches that existed at the time, one based on risk aversion, another not.

As mentioned in section 1.2, several authors assume risk aversion on part of the companies. Within that tradition, Domar & Musgrave (1944) showed that taxation may encourage risk taking,
inducing more investment than under no taxation. They did not use vN-M expected utility, which was just being developed in 1944, but Mossin (1968), Black et al. (1982), and Fraser (1998) have similar results based on expected utility theory. The result relies on assumptions about details of the tax structure, in particular loss offset provisions. But Garnaut & Clunies Ross state without conditions that “risk aversion causes the supply price of investment [the required expected return] to rise if a project is subject to [. . .] various taxes or levies, e.g., . . . proportional taxes on profits” (p. 275). Since there is no formal argument, it is difficult to see how they arrive at a different conclusion from that of Domar, Musgrave, and Mossin when assumptions are so similar.

Garnaut & Clunies Ross (1975) also mention other issues; the transfer pricing problem (see section 6.3), the creditability of RRT payments towards taxes in other countries, and the possibility of combining RRT with CIT. Although not unimportant, the two latter topics are left out of this review. The authors followed up with several other articles, some with other coauthors, and then a book, Garnaut & Clunies Ross (1983), which covers the field with a broad, mostly verbal discussion. The advantage of including many aspects is that the discussion is comprehensive. Hardly anything has been left out. The disadvantage is that it is difficult to end up with a clear conclusion, neither on what is the optimal system nor optimal tax rate(s). Something similar can be said about more recent documents from the IMF and the World Bank.

For the IMF, Baunsgaard (2001) concludes that “It is unlikely to be possible to design one optimal fiscal regime suitable for all mineral projects in all countries. Countries differ, most importantly in regard to exploration, development and production costs; the size and quality of mineral resources; and investor perception of risk. Likewise, projects may differ sufficiently that some flexibility is necessary in deriving an appropriate fiscal regime” (p. 30). The paper includes a table (p. 16), in part adapted from Garnaut & Clunies Ross (1983, p. 332f). It gives a comparative assessment of eight different stylized tax schemes, giving them $8 \times 9$ marks on nine different criteria. But “it is not possible to provide an overall quantitative assessment of each
tax” from the table.

For the World Bank, Otto et al. (2006) conclude that “Countries geological, economic, social, and political circumstances make each nation unique, and an approach to royalty taxes that is optimal for one nation may be impractical for another” (p. 276). The study contains a table which compares different systems on different criteria (p. 63). Stating that profits based royalties (in the present paper called taxes) do not distort investment decisions, they seem to ignore the problem of insufficient loss offset. Previous studies for the Bank were written by Virmani (1985, 1986), with particular focus on oil. He concludes in favor of RRT on efficiency grounds, and emphasizes the need to include other applicable taxes (often a CIT) in the analysis.

A representative paper in the tradition of comparing tax systems is Kemp (1992), one of a series of related papers by Kemp and various coauthors. Petroleum taxes in the UK, Norway, Denmark, and the Netherlands are compared. A set of scenarios for oil prices, as well as extraction and cost data for five representative fields, are constructed based on the author’s experience and judgment. After-tax internal rates of return and net present values at a 10 percent real discount rate are calculated for companies, under the alternative assumptions of no other activity or full tax deductability against other income. There is no analysis of uncertainty, and the high real discount rate applies to all cash flows. The conclusions on average tax rates and progressivity are determined by the choice of these methods, see section 6.2 below. An indication of weaknesses in the method is that the analysis implies that “the Danish system collects a very substantial share of any economic rents to the state,” while in fact, the rent tax in Denmark has collected very close to nothing, due to its generous up-lift.

4 HOW TAXES DISTORT DECISIONS

While Kemp (1992) only considers whether a project is started or not, several studies look at more detailed analyses of distortions to decisions, using a variety of methods. Analysis of effective
marginal tax rates have a general scope, in that they illustrate (non-)neutrality without specifying
the production possibilities. However, in order to quantify average tax rates and the effects on
extraction output or rent, one needs to specify production or cost functions. Along such lines,
several studies leave the exploration phase out of the analysis, some focus on whether and when
to start development, while others neglect this and focus on scale of development or the time
path of extraction after development.

Boadway et al. (1987) define marginal effective tax rates as a wedge between the rate of return
before and after tax for a marginal project. This is a different concept from the marginal rates
mentioned in the beginning of section 3 above. Those are simply the percentage to be paid of a
marginal change in income and the percentage to be refunded through deduction of a marginal
change in cost. The simpler concept was, e.g., used by Smith (1997) to analyze Russian petroleum
taxation. For a neutral cash flow tax of 80 percent the marginal effective rate would be zero
according to the definition of Boadway et al. (1987), while the marginal tax rate would be 80
percent on both income and costs according to the simpler concept.

Boadway et al. (1987) consider a deterministic model of mining, and calculate tax rates for
various mining assets in the Canadian provinces Ontario and Quebec. The findings are that many
marginal rates were negative, so that taxes are distortionary (but in direction of subsidies) and
do poor jobs in collecting rent. Their first table of effective marginal tax rates assumes that there
is always sufficient rent so that companies effectively enjoy the tax values of all deductions at
the margin. Since they do not have data on the extent of effective deductions, they also include
a table with the alternative assumption that one of the allowances is constrained by insufficient
rent. Boadway & Keen (2008) extend the discussion. One qualification they mention is that
typical analyses of such taxation concentrate only on host country tax rates, neglecting taxation
of an international company by its home country, and neglecting taxation of the shareholder.

Slade (1984) is an example of a study dealing with average tax rates. She estimates a cost
function for copper mines, taking both the intertemporal constraint and the processing of ore into the model. (She admits (p. 146) to ignoring the important exploration phase.) Based on the estimated model, she calculates what distortions will occur due to imposition of various taxes and price controls. The deterministic analysis uses numerical methods, but checks for robustness by varying non-estimated parameter values. Taxes will typically lead to both tilting of the time profile of extraction, less extraction and less intensive processing (less final metal output). The second and third of these effects dominate, i.e., effects on total final output, not the intertemporal tilting. On tilting, there is the unexpected result that royalty leads to higher extraction in earlier years, lower in later years.

Such results should not be seen as valid for all types of resource extraction. Whether they also hold for petroleum, coal, or other metals are empirical questions. Lund (1992) is more restrictive than Slade, considering only scale of development of an oil field (number of platforms and wells), not tilting of the intertemporal profile of extraction. The main contribution in that study is the analysis of imperfect loss offset, see section 6.1 below. The focus on tax effects on scale of investment (“development”) and intensity of operations, as opposed to the intertemporal profile, can be supported not only by findings in Slade (1984), but also by reference to Campbell (1980). He finds that the most important decision is investment, i.e., installation of extraction capacity. Afterwards, operating costs are often so low that extraction will take place at full capacity.

5 RISK SHARING: FIXED FEES OR TAXES?

Many contributions consider taxation without mentioning fixed fees as an alternative. Since fixed fees are not a topic per se here, only the literature which discusses auctions as alternative to, or in combination with, taxation will be considered.

A seminal paper is Leland (1978), with a thorough theoretical analysis of optimal combination of the two when both companies and government are risk averse, or, as extreme cases, risk
neutral. Both are assumed to maximize vN-M expected utility. At the outset Leland considers the possibility that there might be perfect markets for state contingent claims, so that companies would instead maximize market value in the interest of shareholders. He dismisses this because a “variety of considerations conspire to make the actual environment diverge from the perfect market paradigm” (p. 414). He mentions transaction costs, information asymmetries, bankruptcy costs, and managers’ self interests as reasons to assume risk aversion instead.

The first part assumes that information is symmetric and companies’ actions are not affected by taxation. Then these assumptions are relaxed. The model assumes that companies make bids for leases before the state of the world is known, but knowing what tax payments will be required in all possible combinations of states of the world and actions by the lessee. The companies compete to the extent that they get no increase in expected utility due to winning a lease. Knowing this pattern of behavior, authorities announce payment schedules before the bidding in order to maximize their (the nation’s) expected utility.

One result is that only if companies are risk neutral will authorities rely solely on fixed fees. Only if authorities are risk neutral will they rely solely on taxes. If both parties are risk averse to some extent, both types of payments will be used. There are further results on the concavity of the optimal payment schedule, which depends on the relation between risk tolerances of companies and authorities. There are also results on effects of shifts in the probability distributions of values. With decreasing absolute risk aversion for both parties, a higher value (in expected utility terms) leads to higher optimal tax schedules, also in relative terms. Leland points out that this indicates the suboptimality of keeping a fixed royalty rate of one sixth for U.S. petroleum over fifty years. More surprisingly, a riskier environment leads to lower optimal tax rates. This is explained by the fact that the companies get zero expected utility anyhow, whereas the government will want less exposition to the increased risk. The article concludes with an assessment of some existing arrangements, in particular petroleum royalty in the U.S., and taxes (or profit sharing, as Leland
calls them) in other countries. The latter are recommended on the basis of the analysis.

Apart from avoidance of royalties, there are some problems with these policy recommendations. There is a question whether risk aversion describes the behavior of these companies better than market value maximization. But even then, it will be very difficult to come up with any precise recommendation. There is no reason to believe that all companies under one jurisdiction have the same risk aversion at any point in time, or that it does not vary over time. How to measure it, or that of the government, is unclear.

Emerson & Garnaut (1984) extend Leland (1978) to include more detailed policy recommendations. They also consider risk averse behavior due to assumptions which are alternative to vN-M expected utility. In addition to Leland’s reasons for recommending taxes on rents, they consider sovereign risk, the possibility experienced by companies of unannounced changes in the tax system. They claim that the “most nearly ideal system of conditional payments in current application is the Resource Rent Tax” (p. 140, their emphasis), in part because tax payments come late, reducing sovereign risk.

Fraser (1998) considers vN-M risk averse firms, specified to mean-variance preferences, based in the numerical analysis on a normal distribution. Deposit size is uncertain, while price is assumed known. (Fraser (2000) considers price uncertainty in a similar model.) The company decides on extraction capacity before deposit size is known. When the deposit exceeds the capacity, the difference is lost. Fraser analyzes how an RRT with imperfect loss offset could be combined with fixed fees, set discretionary or through auctions. It is shown that RRT can lead to over- or underinvestment compared to a no-tax situation. For constant relative risk aversion less than unity there are interior solutions for the pairs of tax rate, threshold rate which achieve neutrality in this sense. This means that for a given threshold rate the company’s optimal investment choice is first an increasing, then a decreasing function of the tax rate as this goes from zero to unity. The Domar-Musgrave effect dominates for tax rates close to zero, but the concave after-tax profit
function dominates for higher tax rates.

Fraser (1998) goes on to “investigate the potential for the government to choose the structure of the RRT so as to maximise expected government revenue from the allocation of a mining lease subject to the RRT, while at the same time leaving the firm’s preferred level of investment unchanged” (p. 116). The constraint imposed in the last part of this sentence is not well explained. Risk aversion will restrict investment in absence of a tax. It is not clear why authorities would not want to encourage a higher investment level.

Sunnevåg (2000) observes that a combination of RRT and auctions may be preferred to relying on auctions only, due to political (=sovereign) risk. If only a fixed fee is paid, and realized prices or quantities then turn out favorably, there will be political pressure to capture windfalls. Companies may suspect that this is in effect asymmetric, with no compensation for bad outcomes. Sunnevåg (2000, p. 15) mentions this, see also Lund (1999, p. 218). It may be more credible to combine a fixed fee with a tax at such a high rate that it captures much of ex post variation. One point which is not mentioned in the literature, is that the very existence of rent taxes may lead bidders to expect asymmetries and thus reduce bids. If so, this is an argument against the combination of fixed fees and rent taxes. If a rent tax is in place from the outset, this may make it easier for governments to increase its rate in case of large discoveries or price increases.

Mead (1994) is a prominent example of an author who considers the alternatives, but draws a very clear conclusion in favor of cash-bonus bidding alone. The article has several suggestions for improvements in the U.S. system, but finds that it is superior to alternatives. The arguments are in part theoretical, but also based on empirical research, in particular Moseidjord (1981), who investigates whether there are indications that auctions of petroleum leases on the Outer Continental Shelf in the U.S. have not captured the whole rent. The leases were acquired 1954–1969, with production data ending in or before 1979, and with projections made for the subsequent period where relevant. The finding is that the average after-tax return on equity was 10.74%,
while it was 11.8% on average in the U.S. manufacturing sector.

Since companies did not earn excessive rates of return, this is claimed to indicate that there is sufficient competition, so that the payment for the lease captures the rent. It is not clear how Mead explains this outcome in light of the sharp increase in oil prices during the 1970’s. For auctions occurring in the 1960’s, with production in the 1970’s, the bidding was probably based on price expectations well below those that were realized. Whether there were large surprises in geology or costs is less obvious. If not, the companies paid too much, and were lucky to be compensated by the oil price increase. It may be seen as indications of a strong winner’s curse, which is not a good outcome for anyone in the long run. In any case, the test based on one output price path is hardly sufficient to settle the question. Mead (1994) dismisses the argument from Leland (1978) that companies may be so risk averse that they are only willing to pay a low price for leases. Again the empirical evidence is used in the argument. A more recent account of the U.S. experience is found in Boué (2006).

Considering risk sharing, there is another approach to the problem. Blitzer et al. (1984) ask the same question as Leland, Emerson & Garnaut, and Fraser, but rely on different assumptions in their answer. Instead of using the concept of risk aversion as such, they rely on portfolio theory and to some extent financial markets, but with incomplete international diversification. They observe that both countries and the shareholders of companies hold portfolios, but that these are not similar, contrary to predictions in standard finance models. Some authorities act on behalf of countries which are heavily reliant on a few natural resources for much of their national income, while other countries will import those same resources for the foreseeable future. The covariances between the resource price and the national portfolios have different signs and magnitudes. There are also different national biases in shareholders’ portfolios for various reasons. This has implications for who is better suited to bear the risk. Blitzer et al. (1984) do not go into detail on tax systems, but look at the broader question of contracts, including contract risks
and political risks.

6 OTHER IMPORTANT TOPICS

While the topics below are seen as important, that could also be said about some of those that are left out. There is no mention of the literature on imperfect competition, prevalent in many markets for nonrenewable resources. Also absent are problems with time inconsistency and means to achieve credible commitment (—the term “fiscal stabilization” is sometimes used in this literature).

6.1 Insufficient Loss Offset

Three papers show effects of insufficient loss offset provision under RRT. The tax will reduce realized net value when positive, but will not subsidize negative outcomes similarly. Mayo (1979) shows that under reasonable assumptions this asymmetry will cause some projects never to be undertaken, even though they would have been without the tax. The same point is made by Ball & Bowers (1983), using a model from financial economics. They show that a rent tax without loss offset is analogous in cash flow terms to authorities having a European call option on profits. By invoking standard assumptions from financial economics, the authors are able to quantify the exact value of the government’s tax claim under various assumptions.

The implication of the analysis is to prefer a Brown tax or some other arrangement with payout of negative taxes. Emerson & Garnaut (1984, p. 140) mention this possibility, but seem to view negative taxes as impractical. Even then one might want to increase the likelihood that the loss carry-forward can be effectively deducted. Mayo (1979) argue that a company tax base would allow for deductions between projects (p. 208), the opposite of “ring-fencing” (that each project/plant/deposit is taxed as a separate unit, without allowing deductions from the same company’s activities elsewhere). Garnaut & Clunies Ross (1979) are aware of this, but
nevertheless advocate project based taxation (p. 198), since they give priority to avoiding the possibility that companies overinvest when the threshold rate is set too high. Saunders (1987) looks at the effects of the cross-field allowance introduced in Britain in 1987.

The option analogy method used by Ball & Bowers (1983) is used by Lund (1992) to quantify distortionary effects of petroleum tax systems when companies choose scale of development. The oil price is assumed to follow a GBMD. Numerical results are found by Monte Carlo simulations of option values. This differs from the typical Monte Carlo simulation in that the simulated price process is not intended to emulate actual prices. When the drift term is reduced, this is known in financial economics as the risk neutral process. Under standard assumptions this yields market values of the company’s cash flows after tax. The results show large distortions if measured as deviations in costs (e.g., number of wells or platforms), but smaller measured as deviations in net value (or production), since there are decreasing returns to scale.

Zhang (1997) also uses financial valuation models, assumes that the oil price follows a GBMD, and analyzes the effect of two different tax systems on a stylized project. One is the RRT, the other a simplified version of the British Petroleum Revenue Tax (PRT). As opposed to Lund (1992), Zhang does not consider the scale of investment, but instead whether taxes distort the choice of whether and when to invest. This is analyzed in a real options model with an analytical solution. The result is that RRT cannot be neutral, but a stylized PRT can, provided that the uplift is set so as to allow for the option value.

The non-neutrality result for RRT in Zhang (1997) has to do with imperfect loss offset. As explained in section 6.2 with reference to Fane (1987), a tax will be neutral if the loss offset and other deductions are non-stochastic and the deviation from a constant-rate cash flow tax has a present value of zero at a riskless interest rate. This neutrality also holds in real option models.
6.2 Risk Attitudes and Discount Rates

As mentioned in section 1.2, there is a fundamental difference between two sets of assumptions regarding companies’ behavior under uncertainty. This section will spell out some consequences in more detail.

The assumption that companies behave as if they have risk aversion, implies that almost all tax systems are non-neutral. Most actual tax systems are distortionary under conditions of full certainty, typically by having higher marginal tax rates on the revenue side than on various types of costs (but see Boadway et al. (1987) for examples of the opposite distortion). Under uncertainty there will be a counteracting effect of sharing risk with the government, encouraging higher activity. Under some circumstances this may lead to an interior solution to the problem of neutral taxation: Some set of tax rates may exist for which the two effects cancel each other out at the margin, cf. Fraser (1998, 2000).

An assumption that companies maximize market value has rather different implications. Value additivity is assumed to be standard knowledge in the business community, mentioned by a leading textbook as one of the seven most important ideas in finance (Brealey & Myers 2000, p. 1008). For tax authorities it is a crucial question whether taxes could be designed based on this assumption, that companies behave according to the textbook. The assumption has been influential in the analysis of taxation under uncertainty in public economics since Fane (1987). He shows that a Brown (1948) cash flow tax is then neutral, since it acts cash-flow-wise as just another shareholder. It is possible to maintain the neutrality if some cash flows (e.g., tax value of deductions) are postponed in time, provided that interest accumulates so as to leave companies indifferent to the postponement. The result is generalized by Bond & Devereux (1995), building on Boadway & Bruce (1984).

But what interest rate is needed? Using the principle of value additivity, it is clear that the cash flow postponement can be valued separately. If the postponement happens with full certainty,
the appropriate rate is the risk free interest rate. The tax system is neutral if the deviation from a cash flow tax is non-stochastic and has zero net present value at that interest rate. While this result by Fane (1987) is theoretically uncontroversial, it seems to be disconnected from much of the preceding literature on rent taxation, and also from the practice of many companies. Practice is typically to apply one (and the same) discount rate to (all elements of) the net cash flow of a company, regardless of the specific risk of each element, cf. the survey by Graham & Harvey (2001). Garnaut & Clunies Ross (1975) have a similar idea: The rate at which deductions (or losses) are allowed to accumulate is ideally the “supply price of investment” which depends on “investors’ attitude to risk” (p. 273) among other things. While it is certainly true that RRT deductions are not risk free, it is equally true that they do not have the same risk characteristics as before-tax cash flows.

Most real-world tax deductions are risky, although to different degrees. Intuitively, a deduction is close to risk free when the net tax base is much larger, depending also on correlations. If the tax code for an RRT or another tax includes one or more specified interest rates, at which losses are carried forward, there does not seem to exist any practicable suggestion for how the rate(s) could depend on project specific details affecting riskiness of deductions. Studies trying to quantify such effects have had to make some simplifying assumptions or rely on numerical solutions. The risk is not easy to describe analytically, in particular not in many periods. Lund (2005) has an analytical model in one period, Zhang (1997) has an analytical model in many periods, while Lund (1992) resorts to simulation in order to find the finance-theoretic value in many periods.

From a policy perspective, it may be possible to ensure that the deductions are (perceived as) close to risk free. Summers (1987) argues that “On balance, it seems fair to conclude that depreciation tax shields represent an essentially riskless asset” (p. 298). This is usually not the case for all deductions in resource extraction, due to higher tax rates, high uncertainty, and, in many countries, ring-fencing. The petroleum tax reform suggestions in Norway in 2000 and in
Denmark in 2001 tried to get closer to certainty for deductions, and accordingly applied a risk free interest rate for carry-forwards. Lund (2002b) gives details. In both countries there would be no ring-fencing, except around a company’s total petroleum activities. In Norway there was a suggestion that if a company closed down its operations without earning the full tax value of deductions (due, e.g., to exploration with no discoveries), it could sell the tax position. In Denmark the suggestion was a refund from tax authorities. In this way there would be full loss offset, provided that the risk free interest rate actually made companies indifferent between receiving tax values of deductions now or, with interest, later. The main purpose of the suggested reforms was to encourage new entrants, who had suffered from long lag periods (and uncertainty) before being able to take advantage of tax shields. Bjerkedal & Johnsen (2005) give more details.

For the reform efforts in these countries it was crucial to apply separate discounting for different cash flow elements. While the reforms went far to achieve neutrality, this could not be understood by oil companies (or anyone) who applied one risk-adjusted discount rate to the net cash-flow. Another topic which has received much less attention is whether the interest rate should be an after-tax interest rate. Lund (2002b) discusses this and shows how the views of the petroleum tax reform commissions in Norway and Denmark differed at this point. Lund (2002b) shows that there are different views of this in the more general literature on taxation of companies and their shareholders. If the marginal investors’ alternatives are taxed, an after-tax interest rate should be used, cf. equation 12.11 in Dasgupta & Heal (1979).

6.3 Transfer Pricing and Income Shifting

Within studies of international taxation, the topic of transfer pricing is well known. Rent taxation exacerbates this problem, which can also occur between sectors in one country. The problem is one important argument for relying on fixed fees instead of higher tax rates, cf. Mead (1994). As a method to avoid transfer pricing, authorities will require arm’s length prices to be used. It
is easier to establish these for resource output than for the costs of resource extraction. Costs are made up of numerous inputs, often tailor-made. Thus the problem is larger on the cost side, borrowing costs and insurance included. The term income shifting is broader than transfer pricing, including also real transfers, such as testing new equipment in a sector with high tax rates.

Osmundsen (1995, 1998) has principal-agent models, in which authorities impose tax schedules which do not rely on reported costs at all. This follows from the somewhat extreme assumption that traditionally monitored self-reporting of costs contains no useful information. Authorities are left with a problem of regulation under asymmetric information. Companies, which have different license areas, are supposed to have different types, i.e., different unit costs, unknown to authorities, whereas the output values will be common knowledge. The optimal solution is to present companies with a schedule of payments to be made, dependent on the output value. The schedule can be implemented as a set of alternative combinations of fixed fees and royalties. They will induce truthful self-reporting, i.e., a company’s type will be revealed by the choice it makes. Osmundsen (1998) has an extension to a two-period model. In order to arrive at a solution, one can then either assume that types are uncorrelated over time, or, as Osmundsen does, that authorities can commit to tax schedules over time.

Lund (2002a), building on Gordon & MacKie-Mason (1995), instead has a model where taxes allow deductions for traditionally reported operating (or investment) costs. Companies can shift income from a jurisdiction with a high marginal tax rate to a jurisdiction with a low rate, but only at a (non-traditional) cost. This cost is quadratic in the amount to be shifted, and could comprise both costs of concealing actual net income and, e.g., costs of transportation of equipment. The model is constructed so that if it were not for the possible income shifting, authorities would want a rent tax at a rate arbitrarily close to 100 percent, whether they wanted to maximize tax income or social surplus. Introducing costly income shifting can lead to two different results, depending
on model parameters. If the output price and/or the transfer cost is high, relative to operating costs, then royalty will not be used, but instead a rent tax arbitrarily close to 100 percent. If not, there will be a combination of rent tax at some lower rate and a royalty, with more reliance on royalty when output price is lower, transfer costs lower, and operating costs higher. Both the possible reliance on a rent tax alone and a discontinuity in the solution are somewhat surprising theoretical results. The model is difficult to apply in practice, as admitted by Lund (2002a).

Boadway & Keen (2008, p. 43) are skeptical of principal-agent contracts, arguing that they are too complicated to implement and too distortionary. They claim that a “reasonably good tax audit system” will allow “a profit tax system to collect reasonable rents.” In Fraser (1999, p. 273) there is a third alternative, that “the government and the firm negotiated an agreement over the allowable cost per unit of production.” This may suffer from asymmetric information problems. Moreover, unforeseen possibilities and problems in extraction will create need for frequent revisions.

In summary, the arguments for any of the approaches seem incomplete. The theoretical models are quite stylized, and some empirical research would be welcome in order to decide how to tackle the problem of income shifting.

6.4 Is Tax Competition a Concern?

Within the literature on taxation in open economies, tax competition among countries have an important role. While mobile factors can escape high tax rates by moving to other countries, immobile factors can not. This is a separate, strong reason for imposing higher tax rates on resource extraction, in addition to those that could be used in closed economies.

However, oil companies, and recently some academics, have argued that there is tax competition in this type of activity as well. If tax rates are high, the companies will prefer to move to another country. The resource cannot be moved. But Osmundsen (2005) argues that the companies have
unique factors of production, such as skills and technology, which they only use where it is most rewarding. He implies that a country is limited in its ability to tax resource extraction by the tax level in other countries competing for attention of the same companies. Boadway & Keen (2008, p. 48) have reservations about this: One “would expect high rewards to expand the supply of these scarce factors, at least in the medium term, just as one would expect a shortage of oil rigs to lead to an increase in their price.”

Lund (2001) asks why a company in (a previous publication of) Osmundsen’s (2005) model undertakes only that project which gives the highest reward after tax to its scarce factors of production. The question is why factors cannot be duplicated. Technology can be duplicated, and the skills of employees can be transferred to others through training. Those skills that cannot are the property of the employee, and would not result in profits for the company in a competitive model. Monopsony in the market for engineers could perhaps explain part of the problem, but would hardly be of such scale to explain much. Another point in Lund (2001) is that the Norwegian experience seems to contradict Osmundsen’s model. Comparing Britain and Norway reveals fairly similar offshore petroleum prospects and political and regulatory environment. In spite of higher taxes for long periods Norway (see Kemp (1992)) has been able to attract a lot of foreign investment in the sector.

6.5 What Is the Optimal Tax Rate?

Perhaps surprisingly, many of the studies referenced above pay little or no attention to the level of taxation. Governments and companies both regard this as very important, whereas tax economists who focus on tax neutrality may have nothing to say about the optimal tax rate. Zhang (1997, p. 1107) states that “under such a neutral up-lift rate, varying the tax rate has no effect on the development trigger.” While Garnaut & Clunies Ross (1975) are quite policy oriented, their discussion of tax rates (p. 280–81) is quite vague, whereas they argue strongly
about neutrality, and even more so in Garnaut & Clunies Ross (1979).

The two preceding subsections, 6.3 and 6.4, deal with situations in which the tax rate (both average and marginal) may clearly have importance. The models lead to recommendations on this. This has to do with international comparison of tax rates. But even in a closed economy we have seen that some models lead to an interior optimum for the tax rate. This is true for the models which combine fixed fees with taxes (Leland 1978, Fraser 1998).

Boadway & Keen (2008, p. 10) write, “There is another aspect of the international nature of the resource business that is more puzzling. Host countries evidently care very much how their tax systems compare with others, and are often concerned not to offer regimes that are substantially more onerous. Quite why this is so, however, is by no means obvious.” Several authors compare the tax level of one country with that of others in order to find whether the level is “reasonable.” E.g., Watkins (2001, p. 28) finds that resource tax regimes in Newfoundland and Nova Scotia “do not suffer by comparison with those in other offshore regions, such as the North Sea and Australia.” Moreover, “Overall, then, the regimes are sensible.” Otto (2000, p. 2) states that “Most governments try to strike a balance between government and investor revenue needs by implementing a ‘fair and equitable’ system. Unfortunately, no one has yet been able to determine what an ideal fair and equitable system is.” It is likely that advice to authorities will be more valuable if it is able to answer such questions.

7 CONCLUDING REMARKS

As has been demonstrated above, there are important problems related to our lack of knowledge of the objective functions of companies. The economics profession has not arrived at one model of company behavior which is agreed upon as valid for all those which extract nonrenewable resources. In part this has to do with observable differences between companies, such as small mining operations versus multinational oil companies. The wide variety of policy recom-
mendations in the literature is caused in part by different theoretical traditions and in part by
different interpretations of empirical evidence. But in many cases what seem to be conflicting
recommendations reflect that different studies look at, and make recommendations for, different
circumstances.

Even for a simple problem like the valuation of depreciation tax shields, Summers (1987)
finds that companies deviate from the methods which have been suggested by textbooks since
the 1970’s. He asks how tax policies should respond to the fact that companies seem to make
mistakes, but does not arrive at a definite conclusion. More generally the question is what is
an optimal tax policy if (a substantial fraction of) companies do not behave according to a
neoclassical model. The standard theory of optimal taxation would not work any more, so many
standard results would need to be amended.

When dealing with these issues, one must distinguish between such deviations from standard
theory which can be explained by the companies’ economic situation, and such deviations which
are hard to explain. E.g., if companies have market power, or if their owners are poorly divers-
sified, these are economic facts which may be modeled in order to arrive at sensible tax policy
recommendations.

To end at a positive note, there are some situations in which the same tax policy may be
beneficial in relation both to “neo-classical companies” and others. The companies which behave
as risk averse, not taking advantage of diversification possibilities in capital markets, will typically
underexploit investment opportunities and take on too little unsystematic risk. The Domar-
Musgrave effect means that a Brown cash flow tax with full, immediate loss offset will encourage
investment by these companies. At the same time this tax is neutral in relation to companies
which are well diversified. Lund (2000, sect. 8.2) points out that the tax works in the right
direction for both types of companies. Sørensen (2005) has a model of this, which leads to an
optimal tax policy. Although the information needed to implement an exactly optimal tax rate
may be difficult to obtain, this is at least an example that all is not dark.

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