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Rent Taxation for Nonrenewable Resources

Diderik Lund

Institutions: University of Oslo

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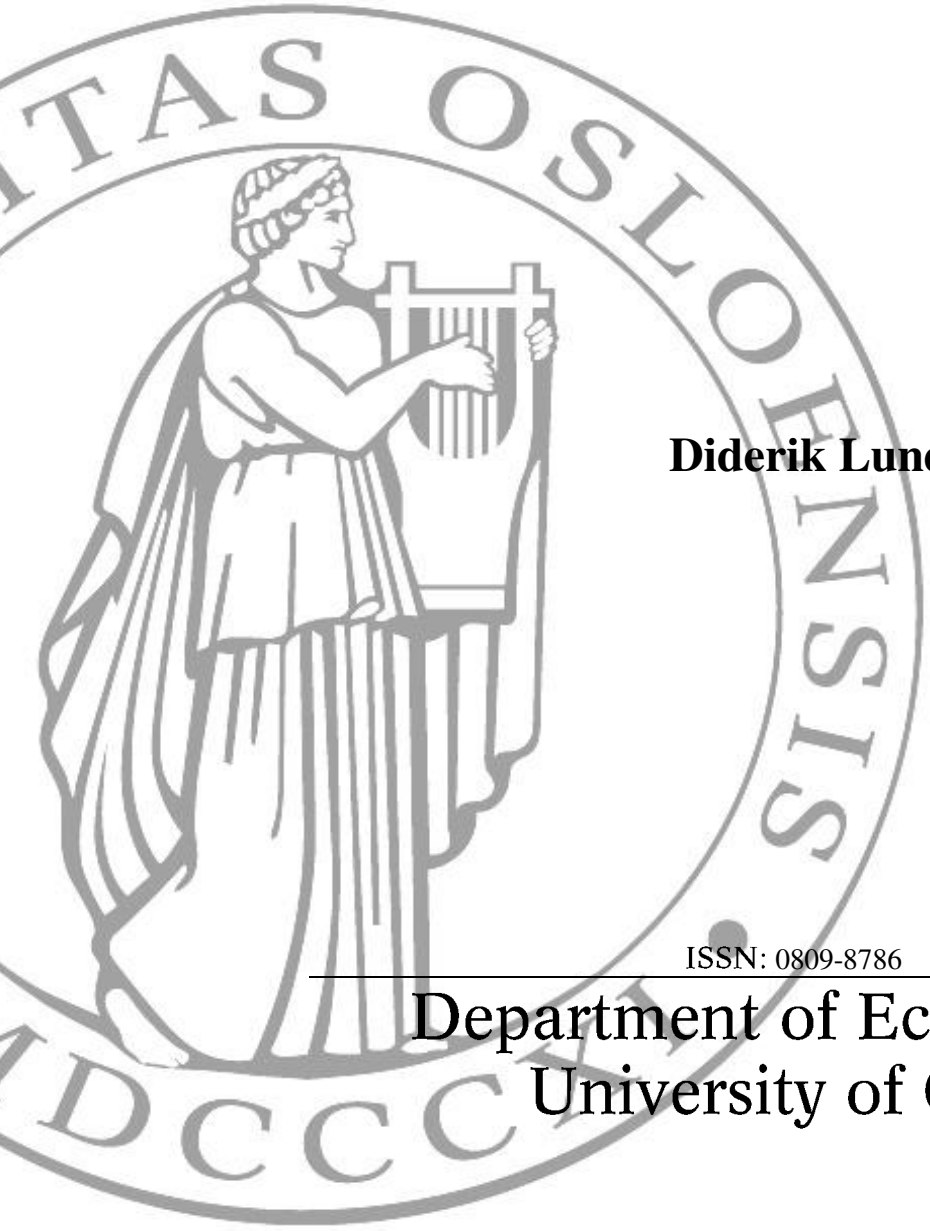
No 01/2009

Rent Taxation for Nonrenewable Resources



Diderik Lund

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Department of Economics
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P. O.Box 1095 Blindern
N-0317 OSLO Norway
Telephone: + 47 22855127
Fax: + 47 22855035
Internet: http://www.oekonomi.uio.no
e-mail: econdep@econ.uio.no

In co-operation with
The Frisch Centre for Economic Research

Gaustadalleén 21
N-0371 OSLO Norway
Telephone: +47 22 95 88 20
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Rent Taxation for Nonrenewable Resources[1]

Diderik Lund
Department of Economics, University of Oslo
e-mail diderik.lund@econ.uio.no

Key words: natural resources, rent tax, royalty, oil, minerals, energy

Abstract: The literature on taxation of rents from nonrenewable resources uses different theoretical assumptions and methods and a variety of empirical observations to arrive at widely diverging conclusions. Many studies use models and methods which disregard uncertainty, investigating distortionary effects of different taxes on whether, when, and how to explore for, develop and operate resource deposits. Introducing uncertainty into the analysis opens a range of challenges, and leads to results which cast doubt upon the relevance of studies which neglect uncertainty. There are, however, several ways to analyze uncertainty, regarding companies' behavior, resource price processes, and diversification opportunities, all with different implications for taxation. Methods developed in financial economics since the 1980's are promising, but still not in widespread use. Some more specific topics covered in this review are optimal risk sharing between companies and governments, time consistency and fiscal stability, the relationship between taxes and discount rates, and transfer pricing.

JEL CLASSIFICATION NUMBERS: B20, H20, H25, L71, O13, Q38

[1]This is a critical review of the literature, submitted December 1, 2008, to the *Annual Review of Resource Economics,* vol. 1, 2009, http://www.annualreviews.org/institutions/2009_econ.aspx#resource.

1 Introduction

In many countries extraction of nonrenewable natural resources is an important source of government revenue. This is true in different countries for petroleum, coal, metals and other minerals. Recent overviews, Baunsgaard (2001), Sunley et al. (2003), and Otto et al. (2006), show world-widespread use of various taxes specific to these sectors.

To minimize the need for distortionary taxes, economists have recommended maximizing 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. When resource prices are high, large rents may lead to 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 reviews 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 and extraction paths for a nonrenewable resource. Section 3 focuses on studies directed at policy reforms. Some have been highly influential, despite some weaknesses which are pointed out. Section 4 discusses various approaches to the analysis of tax effects on companies' decisions. Section 5 shows how auctions have been promoted as alternative to taxation, and possible advantages of combining the two. Section 6 contains miscellaneous topics. Section 7 offers concluding remarks.

1.1 Delineation of the Topic

Governments have revenues from resource activities in various legal and economic forms. A company extracting a nonrenewable resource may have ownership of the resource, or may obtain license to exploit it. The company's resource extraction is subject to taxation, in some cases together with a larger part or the whole company. "Taxation" means that payments depend on realized outcomes 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 covers only parts of the literature on fixed fee systems.

Equity participation by governments is not covered. The cash flow implications of such arrangements may be interpreted as taxation, while ownership rights are outside the scope of this review. However, governments regulate many aspects of the activity, which has implications for the practical interest in analysis of taxation. If all companies' choices are

severely regulated, there may be little actual influence from distortionary taxes. In practice some choices are less restricted than others, but this varies greatly between countries and types of resources. If one wants to exploit the expertise found in private-sector companies, they must be left with important decisions to make, which unfortunately gives room for tax distortions.

"Royalty" denotes taxes on gross production value. Parts of the literature use 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), "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. The justification 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 units of the resource. This allows a distinction between rent taxes and excise taxes. A rent tax is 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. Pigouvian taxes to correct for externalities are also not discussed.

1.2 Alternative Models of the Behavior of Companies

To predict effects on behavior of companies, one needs assumptions about how companies make decisions. Different studies use different assumptions. This subsection will highlight some differences which are particularly relevant for the following sections. We first look at two alternative assumptions regarding risk. Then we mention an unconventional assumption related to the volume of rents.

The first alternative is to assume risk aversion on part of companies. The assumption is often that companies maximize von Neumann & Morgenstern (1947) expected utility (vN-M hereafter). 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). Most studies in this tradition have no consideration of diversification possibilities for the company or its shareholders. Variance or some other measure of dispersion of profits is sometimes taken as measure of risk. There are three possible complications at this point. First, if the company diversifies, the covariance between one project and the rest of its portfolio takes over as risk measure. Second, if shareholders diversify, companies

will maximize market value (see next paragraph). Third, managers may act in their risk averse self interest, neglecting preferences of shareholders, cf. Leland (1978).

The second alternative is to assume that companies maximize market value, supposedly in the interest of shareholders. The market value is additive, meaning 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 no model of financial economics is established as the final truth about financial markets or decision making, there are arguments for both assumptions.

Finally in this section, an assumption which has received some attention recently should be noticed. Osmundsen (2005) assumes that oil companies, in order to start a project, require some minimum volume of rent, sometimes called "materiality." Again, this assumption has far-reaching implications. Even an otherwise neutral rent tax with a low rate will then cause some projects to move from being acceptable to unacceptable.

2 Equilibrium Models

Since Hotelling (1931) the analysis of economics of nonrenewable resources has been based on dynamic partial-equilibrium models of the resource market, 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 determine the sequence of extraction.

Introduction of taxes in Hotelling (1931) models is discussed in chapter 12 of the otherwise influential textbook by Dasgupta & Heal (1979). 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 world-wide taxation. All extraction is subject to the same tax. 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, Gaudet & Lasserre (1986) and Lindholt (2008) being exceptions.

Few studies have analyzed resource taxation in intertemporal general equilibrium models, in which the interest rate is also endogenous. Groth & Schou (2007) have a 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. All of the resource will be used in the limit in infinite time. The study shows that the resource use will decline exponentially in the long run, with the decline rate possibly affected by taxation. The model cannot analyze distortions from labor income taxation, as there is no labor-leisure choice. It suffers from the unrealistic feature that the same taxes are applied on all natural capital, world-wide. A main result on resource taxation is that a tax on capital gains on natural capital leads to too little conservation of the resource, thus impeding sustainable growth.

There is some evidence (Krautkraemer 1998, Slade & Thille 2009) 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 (GBM) is hardly an equilibrium price process. GBM is nevertheless assumed in four studies to be discussed below, Ball & Bowers (1983), Lund (1992), Zhang (1997), and Blake & Roberts (2006), who claim (pp. 98–99) that, although unrealistic, the GBM is acceptable for their purpose.

3 Comparing Tax Systems, Suggesting Tax Reforms

The basic problem for a 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 wedges between rates of return before and after tax increase with tax rates. In a closed economy, this will be counteracted if interest income and all corporate income are taxed at the same rate, cf. 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 implies 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.

Royalties also distort decisions. Without cost deductions they make resource units with high costs unprofitable. In actual tax systems there may be many complicating features,

including taxes and deductions at several levels. A first approximation to 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 rate on cost reductions. 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 Resource Rent Tax (RRT). It intends to give a deduction equal in present value to the investment itself, typically exceeding most CIT systems' depreciation allowances. A generalization of the idea is found in Boadway & Bruce (1984). Investment, indeed any yearly negative net cash flow, is carried forward for later deduction, with interest accumulation, as soon as revenues allow. If the tax base in subsequent years is sufficient to allow complete, effective deduction of the carry-forward, this can ensure that only the rent is taxed.

Authorities must determine an interest rate for the accumulation. The intention is that companies be 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. The difficulties in assessing the rate of return, and various consequences of this, are the topics of much of the debate which followed (Sumner 1978, Dowell 1978).

Other authors (Mayo 1979, Ball & Bowers 1983, Lund 1992, Smith 1999) focus on the possibility that the income stream in later years may be insufficient to allow for an effective deduction. Typically, RRT offers no payout if the income stream is too small. Garnaut & Clunies Ross (1979, p. 196) recognize this problem. The tax will reduce realized net value when positive, but not subsidize negative outcomes similarly. Mayo (1979) shows that under reasonable assumptions this asymmetry will cause distortions. The implication of the analysis is to prefer a Brown (1948) 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) argues 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 in the same company's profits elsewhere). Garnaut & Clunies Ross (1975) are aware of this, but nevertheless advocate project based taxation (p. 198), giving priority to

avoiding the possibility that companies overinvest when the threshold rate is set too high. Saunders (1987) looks at effects of the cross-field allowance introduced in Britain in 1987.

Inability to decide on the correct rate for interest accumulation leads to a suggestion to use two or three different rates. If and when 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 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.

While risk aversion is in the title of Garnaut & Clunies Ross (1975), there is no formal definition of it, only an informal description of a concave objective function (p. 273). This vagueness conceals some problems. Their arguments can be contrasted with alternative approaches that existed at the time.

Domar & Musgrave (1944) show that taxation may encourage risk taking, inducing more investment than under no taxation. They do not use vN-M expected utility, 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 (1975) 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 below), the creditability of RRT payments toward 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 hardly anything has been left out. The disadvantage is that it is difficult to end up with a clear conclusion, neither on 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 8×9 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).

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. A curious weakness in the results is that "the Danish system collects a very substantial share of any economic rents to the state," while in fact, the rent tax in Denmark 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 marginal tax rates have a general scope, in that they illustrate (non-)neutrality without specifying the production possibilities. However, to quantify average tax rates and the effects on extraction output or rent, one must specify production possibilities. 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 time paths of extraction after development.

Boadway et al. (1987) define a marginal effective tax rate as a relative 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 gross 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 rates 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. 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.

Krautkraemer (1990) studies the theoretical impact of taxation on ore selection, tilting of the time profile of extraction, and total depletion from a mine. He includes a useful overview of related studies. Slade (1984) 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. Taxes will typically lead to both intertemporal tilting, 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 tilting. On tilting, there is the unexpected result that royalty leads to higher extraction in earlier years, lower in later years. Whether the results also hold for petroleum, coal, or other metals are empirical questions. Deacon (1993, p. 173) confirms that tilting is the less important distortion from a royalty on oil.

Inspired by Hotelling (1931), the interest is in the intertemporal profile. To focus instead on scale of investment in each project can be supported not only by findings in Slade (1984) and Deacon (1993), 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 takes place at full capacity. Many other studies model one or the other type of opportunity set for companies. Sumner (1978) assumes that total extraction from a field is given, while companies choose the constant yearly rate at which to extract. Lund (1992), on the other hand, assumes that companies choose scale of development of an oil field, that total extraction is an increasing, concave function of this, but that the intertemporal profile is constant in relative terms.

Deacon (1993) has perhaps the broadest scope of any of the deterministic tax distortion studies. He estimates and calibrates an optimization model of exploration and extraction by a representative oil company, using data for the lower 48 states of the U.S. from 1859 onwards. He considers distortionary effects of CIT (found to be small), royalty (medium) and property tax (severe). Besides several improvements in methods, the somewhat unusual inclusion of property taxes is interesting.

Another line of authors use models inspired by financial option theory. Generally they find tax distortions exacerbated by uncertainty, effects which could not be discovered by most of the authors cited above, who neglect uncertainty.

Ball & Bowers (1983) observe that an RRT has imperfect loss offset, and that the tax claim is similar to a European call option. Using standard assumptions from financial economics, the authors quantify the market value of the government's tax claim under price uncertainty. Majd & Myers (1985) use a similar approach for the CIT. MacKie-Mason (1990) studies nonlinear taxes with the U.S. depletion allowance as an example. Later contributions with applications to rent taxation include Jacoby & Laughton (1992), Lund (1992), Zhang (1997), Bradley (1998), Blake & Roberts (2006), and Samis et al. (2007).

Besides similar assumptions, the common theme in these studies is valuation of non-linear tax claims, occurring, e.g., due to imperfect loss offset or progressive tax schedules. In most cases the tax claim is convex (but MacKie-Mason (1990) finds an exception), implying that the tax claim increases in value with increased uncertainty. Jensen's inequality is all one needs to show this, but the studies are more elaborate, using the risk adjustment method from modern asset pricing (MAP). This is explained in detail in Jacoby & Laughton (1992), and is the topic of a special issue of the *Energy Journal* in 1998, see Laughton (1998). (MAP and related methods are also called market based valuation, contingent-claims analysis, derivative assets analysis (Rubinstein 1987, footnote 1).) The method is used for real options in resource economics, but among the cited authors, only MacKie-Mason (1990) and Zhang (1997) consider this, i.e., managerial flexibility. Both obtain analytical results in stylized models. Jacoby & Laughton (1992), Lund (1992), Bradley (1998), Blake & Roberts (2006), and Samis et al. (2007) analyze taxes with option-like cash flows using Monte Carlo simulations. These differ from typical Monte Carlo simulations 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.

Lund (1992) considers Norwegian petroleum taxes before and after 1987. He finds large tax distortions if measured as deviations in costs, but smaller in net value, since there are decreasing returns to scale within fields. Blake & Roberts (2006) use the same type of production function to analyze petroleum taxes in Alberta (Canada), Papua New Guinea, Sao Tome & Principe joint with Nigeria, Tanzania, and Trinidad & Tobago. They find strong distortionary effects for the latter two, less for the others.

Zhang (1997) studies effects of two different taxes on the choice of when and whether to invest in a stylized project. One tax is the RRT, the other a simplified version of the British Petroleum Revenue Tax (PRT). 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. It seems that the non-neutrality result for RRT 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.

Bradley (1998) and Samis et al. (2007) give detailed accounts of the method and apply it to stylized projects, oil and copper/gold, respectively. Both consider two alternative resource price processes, GBM and mean reversion. Both highlight the merits of the method relative to traditional discounted cash flow (DCF) analysis, for which there is no theoretical justification in a world of uncertainty.

Nakhle (2008) includes both DCF (chapter 5–6) and MAP (chapter 7). She claims without explanation that, compared with DCF, MAP is "controversial" (p. 116), but also "more useful" (p. 117, p. 128). In spite of usefulness, the newer method is "unlikely to capture many sponsors" (p. 148). Apart from chapters 5–7, the book gives an account of the history and politics of petroleum taxation from a UK perspective, comparing also with other nations.

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 combinations of the two when both companies and government (the nation) 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.

Leland considers various sets of assumptions on information asymmetries and the effect of taxation on companies' actions. Companies compete to the extent that they get no increase in expected utility due to winning a lease. Knowing their pattern of behavior, authorities announce payment schedules before the bidding in order to maximize expected utility for the nation. 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.

Emerson & Garnaut (1984) extend Leland (1978) to include more detailed policy recommendations. In addition to Leland's reasons for recommending taxes on rents, they consider sovereign risk, the possibility experienced by companies of unannounced changes in taxes. 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. Deposit size is uncertain, while price is assumed known. (Fraser (2000) considers price uncertainty in a similar model.) He studies 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 and 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.

To use the results of Leland (1978), Emerson & Garnaut (1984), and Fraser (1998) for policy recommendations entails some problems. 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.

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 (Lund 1999, p. 218; Sunnevåg 2000, p. 15). 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 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, companies may perceive that this makes 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 taxation-based alternatives. The arguments are in part theoretical, but also based on empirical research, in particular Mead et al. (1983), who investigate whether there are indications that auctions of petroleum leases on the U.S. Outer Continental Shelf have not captured the whole rent. Leases were acquired 1954–1969, with production data ending in or before 1979, and with projections made for the subsequent period when needed. 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.

Low returns are claimed to indicate that there is sufficient competition, so that lease payments capture the rent. Mead et al. (1983) recognize that oil price increases in the 1970's were hardly anticipated, so bidding was probably based expectations well below those that were realized. But in the return calculations, these years count less than earlier years, which saw declining real prices. Whatever the reasons are, the fact that returns are lower than in other sectors in spite of higher risks, may be seen (—but see subsection 6.2 below on tax effects on after-tax required returns—) as indications of a strong winner's curse, as noted by Thaler (1988). This 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 exists another approach. Blitzer et al. (1984) ask the same question as Leland, Emerson & Garnaut, and Fraser, but rely on different assumptions in their analysis. Instead of using the concept of risk aversion alone, 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 Topics

While the topics below are important, that could also be said about some that are left out due to space limitations. There is, e.g., no mention of taxation under imperfect competition, prevalent in many markets for nonrenewable resources.

6.1 Time Consistency, Fiscal Stability, and Progressivity

Many of the cited studies contain passages on the importance of stability in tax systems. Garnaut & Clunies Ross (1981) give a historical account of this and related issues. Governments may be tempted to increase taxes after positive outcomes for prices or reserves (windfall profits taxes), while not decreasing them after negative outcomes. High up-front required payments to authorities (typically found under an auction system) in addition to large investments, clearly exacerbates the problem. This contributes to explaining why auctions are most often found in stable political environments with perceived reluctance to impose additional taxes.

Boadway & Keen (2008) point out that if companies realize that governments cannot credibly commit to not increasing taxes, this will lower investment, and thus hurt both parties. This may perhaps be overcome by non-carried equity participation by the government (an up-front payment in the opposite direction of the one mentioned above), or by acquiring a reputation for keeping a stable system. Osmundsen (2008) sketches the game-theoretic argument which allows for an equilibrium without underinvestment in an infinite-horizon game, supported by trigger strategies. But these are not unique equilibria, and many conditions need to be satisfied, so one cannot say that the problem has found its solution. He goes on to consider Norwegian petroleum taxation, finding that "Over the past decade, Norway has shifted to a policy of absolute commitment, where the tax system is unchanging." But he is aware that there may be country specific problems related to attaining this solution.

In some countries governments offer explicit fiscal stability clauses in contracts, promising renegotiations or immunity in the event of future tax increases. One problem is the short lifetime of governments compared to many resource projects, as pointed out by Daniel

& Sunley (2008). They argue that fiscal stability clauses are prone to being overridden by changed circumstances. They mention that clauses are sometimes best seen as smokescreens, which may be circumvented by government actions not covered by the clauses.

When Denmark introduced a fiscal stability clause in 2003, two potential problems were pointed out by Lund (2003). Companies paid both CIT and a rent tax. If international competition later would force authorities to lower the CIT rate, a simultaneous increase in the rent tax rate would be prohibited by the clause. Such a pair of tax rate changes actually happened in Norway in 1992, and a switch from mobile to immobile tax bases is a well known prediction in the public economics literature. The second problem was that the clause could complicate the introduction of Pigouvian taxation.

In addition to questions of whether and how a government may commit itself, comes the broader question of political support. There may be considerable unrest if companies earn large after-tax rents ("windfalls") due to resource price increases or large discoveries. This has lead some authors (notably those connected to the IMF and the World Bank) to recommend progressive taxes. Boadway & Keen (2008, p. 45) argue that "progressive rate schedules may be more robust against political pressures in the event of high return outcomes than are proportional schemes." Similarly, Sunley et al. (2003, pp. 159–60) point out that "Proponents argue that the RRT can enhance contract stability because it automatically increases the government share in highly profitable projects." Daniel & Sunley (2008, p. 6) state that "A robust fiscal regime is therefore adaptable and progressive", and Land (2008, p. 4) argues similarly.

Possible benefits from progressivity must be weighed against distortionary effects. Based on models without uncertainty, Conrad & Hool (1984) show that taxes with variable rates have distortionary effects, and Sumner (1978, p. 9) state that "the basic objection to the resource rent tax is that it cannot simultaneously provide neutrality and progressivity." Under uncertainty, progressivity combined with imperfect loss offset will give the convexity which implies that the tax claim's value increases with higher uncertainty, cf. section 4 above. Bond & Devereux (1995, pp. 67f) show theoretically that "neutrality with a non-constant tax rate requires that the investment project generates a non-negative tax base in every period" (p. 58). Blake & Roberts (2006, p. 101) find that "the two most distorting systems, Tanzania's and Trinidad's, contain a common fiscal component which attempts to capture more revenues for the host government with increasing production."

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 consequences in more detail.

The assumption that companies behave as risk averse, implies that almost all tax systems are non-neutral. Most actual taxes are distortionary under conditions of full certainty, typically by having higher marginal tax rates on the revenue side than on savings on various 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 leads 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 (Fraser 1998), although this is hardly of practical interest (Smith 1999).

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 should be designed based on the assumption that companies behave according to the textbook. Value additivity has been assumed in analysis of corporate taxation under uncertainty in public economics since Fane (1987). He shows that a Brown (1948) cash flow tax is then neutral, since it acts in cash flow terms 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).

What interest rate is needed? Based on value additivity, it is clear that the postponement can be valued separately. If it happens with full certainty, the appropriate rate is the riskless interest rate. The tax system is neutral if deviations from a cash flow tax are non-stochastic and have 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. 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, cf. Lund (2005). Intuitively, a deduction is close to risk free when the net tax base is much larger, depending also on correlations. If the tax code 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.

In 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 deprecation 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 riskless interest rate for carry-forwards. Lund (2002b) and Bjerkedal & Johnsen (2005) give details. This could be obtained by no ring-fencing, sale of negative tax positions, or refund of tax values of unused deductions. A possible objection is that apparently wasteful expenditures would be partly subsidized, possibly allowing experimentation, useful for companies. This could perhaps be prevented by government regulations or equity participation, the latter also allowing governments to learn.

For 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 discount rate to the net cash flow. Based on the finance-theoretic approach, Lund (2002c) shows how this is a mistaken practice when companies operate in jurisdictions which differ (much) in tax rates and investment-related deductions, which companies in resource extraction typically do. Systematic risk (and thus the correct discount rate) of the net after-tax cash flow depends on the tax system. Lund (2002c) gives analytical solutions for stylized linear tax systems, while Lund (2005) extends the analytical solutions to nonlinear cases with imperfect loss offset. When taxes are nonlinear in many periods, numerical methods are needed, and risk-adjusted discount rates are no longer practical tools. Jacoby & Laughton (1992) and Bradley (1998) give numerical examples for a number of realistic cases. Typically the correct discount rate for the expected net cash flow after tax is less than before tax, and decreasing in the tax rate.

Another topic which has received much less attention is whether the interest rate should be an after-tax interest rate. Lund (2002b) shows how the views of the petroleum tax reform commissions in Norway and Denmark differed at this point, and relates it to 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), see also Gaudet & Lasserre (1986, p. 242).

6.3 Transfer Pricing and Income Shifting

Rent taxation exacerbates the problem of transfer pricing, well known in international taxation, but also occurring between sectors in one country. The problem is one important argument for relying on fixed fees instead of higher tax rates (Mead 1994). To avoid

transfer pricing authorities require use of arm's length prices. Establishing these is easier for resource output than for costs. Costs are made up of numerous inputs, often tailor-made. Thus the problem is bigger 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, which can also represent a distortion. Using the notation from the beginning of section 3, one should distinguish between $t_c > t_y$ (overinvestment incentives), $t_c > 1$ (gold plating incentives), and t_c exceeding the t_c of another sector or jurisdiction (transfer incentives).

Osmundsen (1995, 1998) has principal-agent models, in which authorities impose tax schedules which do not rely on reported costs at all, see also Dowell (1978, p. 136). This follows from the somewhat extreme assumption that traditionally monitored self-reporting of costs contains no useful information. Authorities must regulate under asymmetric information, based only on probability distributions of costs. The optimal solution is to present companies with a schedule of payment obligations, conditional on output value. This can be implemented as alternative combinations of fixed fees and royalties. Osmundsen (1998) extends this to a two-period model, inspired also by Gaudet et al. (1995).

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 one with a low rate, but only at a (non-traditional) transfer cost, quadratic in the amount to be shifted. 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. 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 is not 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. 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. They claim that a "reasonably good tax audit system" will allow "a profit tax system to collect reasonable rents." Fraser (1999, p. 273) has 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 and needs 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 cannot. This is a separate, strong reason for imposing higher tax rates on resource extraction, besides those that apply to closed economies.

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) the model of Osmundsen (2005) 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. Dowell (1978, p. 136) also has a discussion of these issues. 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 (see Kemp (1992)), Norway has been able to attract a lot of foreign investment in the sector.

6.5 What Is the Optimal Tax Rate?

Perhaps surprisingly, many studies referenced above pay little attention to the tax level. Governments and companies both regard this as very important, whereas economists who focus on tax neutrality 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).

Theoretical models with international comparisons (subsections 6.3, 6.4) lead to recommendations on tax rates. Even for closed economies there can be interior optima for the tax rate in 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." Maximization of rent tax revenue would reduce the need for other, distortionary taxes. This also raises doubt about the relevance of analyzing a revenue neutral rent tax reform (Deacon 1993).

Several authors compare the tax level of one jurisdiction 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 under uncertainty. 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. Such differences can be modeled. But the wide variety of policy recommendations in the literature is caused in part by different theoretical traditions and in part by different interpretations of empirical evidence.

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.

To end at a positive note, there are some situations in which the same tax policy may be beneficial in relation both to "neoclassical 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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