THEORETICAL PERSPECTIVES ON RESOURCE TAX DESIGN

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Abstract: The importance and complexity of petroleum and hard minerals operations is matched by the importance and complexity of finding effective ways to tax them. Many of these challenges arise in other activities too (exhaustibility of deposits being the main exception), but they take such extreme form in relation to resources as to have led to a proliferation of creative instruments and analytical methods. This paper reviews the challenges for tax policy in dealing with the resource sector, the principal instruments used, and some of the central design issues.

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I. INTRODUCTION

Natural resources are a large part of the wealth of many countries, and the way in which their potential contribution to government revenues is managed can have a powerful impact—for good or ill—on their prosperity and economic development. The challenges to good tax design, however, are formidable, both in the technicalities of dealing with the distinctive features of resource activities and in coping with the interplay between the interests of powerful stakeholders.

The purpose of this paper is to review the most central of these challenges, bringing to bear a perspective drawn from the wider public finance tradition. To a large extent, the literatures on resource taxation in particular and on business and commodity taxation more generally have evolved largely distinct from one another, and indeed the same is true in terms of policy formation. This is surprising and unfortunate. Many of the challenges faced in the resource sector are not qualitatively unique but arise in any business activity; it is just that they loom especially large in relation to resources. The resource tax literature has consequently delved into some issues (how uncertainty can shape the impact of taxation on investors' incentives, for instance) more deeply than has the wider public finance literature. On other issues (such as the design of rent taxes), it has perhaps not fully absorbed advances, theoretical and practical, in wider understanding of the essential issues and possibilities. Part of the purpose here is to bring the mainstream and specialist perspectives closer together. In doing so, the paper is also intended to provide a conceptual framework for many of the more applied contributions in later chapters of this *Handbook*.

The coverage is broad, having in mind oil, gas and mining activities. Specialist treatments are commonly provided for each, reflecting differences in their practical features and associated traditions of tax design.[1] Their considerable analytical similarities as non-renewable resources, however, warrant a unified conceptual treatment: for brevity, the paper uses the term 'resource' to refer to all three.[2] Also for brevity, the term 'tax' is used in a broad sense to include payments to governments (such as royalties associated with the right to exploit deposits owned by the state, or equity participation) that are not taxes in the formal sense of being unrequited, but are compulsory nevertheless.

[1] The chapters by Hogan and Goldsworthy (2009), Nakhle (2009),and Kellas (2009) focus respectively on minerals, oil and gas. See also Sunley, Baunsgaard and Simard (2003) on oil and gas, and Baunsgaard (2001) and Otto et al (2006) on mining.

[2] Renewable resources, such as timber and fisheries, raise quite different resource management (and hence also fiscal) issues.

The coverage is also broad in terms of the design issues addressed. One though is given particular emphasis, running through much of the discussion. This is the question of whether or not resource tax regimes should incorporate some element of progressivity, in the broad sense (rarely defined more precisely) of implying an average tax rate that rises with the realized profitability of the underlying project. This naturally rises to special prominence in public discussions in times of high resource prices, but more fundamentally goes to the heart of many of the fundamental questions of credibility, risk-sharing and efficiency that arise in designing efficient tax regimes for the sector.

The focus of the paper is limited, nevertheless. For the most part, the design problem considered is that of the country in which the resource deposits lie; we do not consider the pricing of final sales (the benchmark instead being one in which resources trade at world prices); governance issues are largely set aside; and so too are environmental considerations. This precludes significant policy problems: resource importing countries could choose to levy windfall taxes on rents earned on imports, for instance, or (perhaps in pursuit of energy security objectives) to impose tariffs; fuel subsidies remain a pressing concern in many countries; governance is a prevalent concern in the sector, whose nature and extent could depend on the tax regime in place; and environmental concerns are particularly prominent in the resource sector at both the local level and, for fossil fuels, through the global public bad of climate change. All these concerns could have powerful implications for efficient tax design, and are neglected here only because the issues that remain merit separate treatment.

The paper first reviews key features of the resource sector that shape the tax design problem, and the extent (or not) of their uniqueness. Section III then examines some of the key instruments that are or might be deployed, and how their combined impact may be measured. Some of the central challenges for tax design emerging from the features highlighted in Section II are considered in Section IV. Section V concludes.

There is some algebra—but it is not in the main text, and can be skipped.

II. What's special about resources?

The resource sector has a number of features that make its taxation not only especially important for many countries but also particularly challenging—though in some respects, as will be seen, it is more straightforward to tax than are many others. Most of these features, it will be argued, are not in themselves unique to resources. What is distinctive is their sheer scale. This section reviews these features, postponing until later discussion of the challenges for the tax design that they pose.

High sunk costs, long production periods

Discovering, developing, exploiting, and closing a mine or oil field can costs hundreds of millions of dollars, and take decades. In mining, for instance, it is nor uncommon for fifty years or so to pass between exploration and rehabilitation. Moreover, the associated expenses are to a large degree incurred early in the life of the project, often prior to the generation of any cash flow, and are then sunk, in the sense they have little if any alternative use. An offshore oil platform may be moved to other fields, for instance, but money spent looking for oil fields (successfully or not) is gone. While significant sunk costs are incurred in other lines of business too—in developing power plants, for example, or in undertaking R&D (analogous to exploration spending) on pharmaceuticals—their pervasiveness and magnitude in resource activities put them at the heart of the problem of sectoral tax design.

The importance of these features is that they pose a fundamental problem of ***time consistency***. While a resource project is still in the design stage, the prospective tax base is highly sensitive to the anticipated tax regime: if investors feel it will be too onerous, they can simply not undertake the project. Once they have incurred the sunk costs, however, investors have little choice: so long as they can cover their variable costs, production is more profitable than ceasing operations, making the tax base relatively insensitive to tax design. The government thus has an incentive to offer relatively generous treatment at the planning stage (the tax base then being relatively elastic), but much less generous treatment once it is in place (the tax base then being relatively inelastic): this is the 'obsolescing bargain' of the resource literature. The importance of this is that it creates a potential inefficiency: the forward-looking investor will recognize the changed incentive that the government will face ex post, and so may be reluctant to invest even if promised generous treatment: they see all too clearly the incentive that the government will have to renege. All this may leave investors reluctant to invest: the 'hold up' problem.

The problem does not arise from any duplicity or ill-will on the part of either the government or investors: it simply reflects the general principle of efficient tax design that tax rates be set in inverse relation to the elasticity of the underlying tax base. The fundamental difficulty is simply the inability of the government to commit in advance to apply the scheme that it would be optimal to impose at the outset: a promise alone may not be credible, since investors know that the incentives even of a wholly benevolent government will change once the investment is made. While this incentive to renege on promised tax arrangements arises whenever investors incur sunk costs, the temptation will naturally tend be greater the more profitable an investment proves. Events in Zambia, Ecuador, and Venezuela during 2008, for example, show that pressures can be especially strong at times of high resource prices.

The prospect of substantial rents

Economic rent is the amount by which the payment received in return for some action—bringing to market a barrel of oil, for instance—exceeds the minimum required for it to be undertaken. The attraction of such rents for tax design is clear: they can be taxed at up to (just less than) 100 percent without causing any change of behavior, providing the economist's ideal of a non-distorting tax. And this appeal on efficiency grounds—which is conceptually distinct from any notion of fairness based on the government's legal or moral claim to ownership of the resource—is reinforced on equity grounds (at least from a national perspective) if those rents would otherwise accrue to foreigners. Equally clear, most recently with the spectacular run-up in commodity prices to the latter part of 2008, is the potential magnitude of these rents in the resource sector. Rent extraction is thus a primary concern in designing resource tax regimes.

The resource sector is by no means the only one in which rents can arise. In a competitive world, they can arise only if there is some factor of production that is in fixed supply (for if there were not, new firms would enter at lower prices and eliminate the rent). In the resource context, the fixity of resource endowments—not just over infinite time but over the fewer years and decades needed to bring new sources online—and the diverse quality of deposits create evident scope for the existence of such rents.[3] In other sectors, rents may arise from fixed factors in the form of protected intellectual property rights, superior management, better locations, as well as from barriers to competition. Again, it is the sheer scale and potential persistence of such rents that marks out the resource sector.

Care always needs to be taken in operationalizing the notion of rents to include all the relevant costs of the actions at issue: failing to do so means that a tax on 'rents' will actually distort decisions. This is not an easy task. It requires, for instance, making appropriate allowance for any risk premium in the cost of capital faced by resource companies and for any part of the return to shareholders that may represent incentive payments to managerial skill. In the resource context, two particular issues loom large.

First, one of the costs of extracting some resource this period is the revenue foregone by the consequent inability to extract it in the future: this is sometimes referred to as 'Hotelling rent.[4] Importantly, however, while these period-specific costs do affect the optimal time profile of resource extraction (as discussed below), they do not affect the rent optimally accumulated over the full lifetime of a project: a firm may incur some opportunity cost today

[3] Diagrammatic treatments of the nature of resource rents are in Garnaut and Clunies Ross (1983) and Otto et al (2006).

[4] Following the classic treatment of these issues in Hotelling (1931).

by restricting output so as to be able to extract more tomorrow, but when tomorrow comes it derives an offsetting benefit. Thus—despite its prominence in the resource literature—the taxation of rents over a project's life does not require any measurement of Hotelling rent, or even any use or understanding of the concept.

Second is the importance of the notion of ***quasi-rents***, meaning rents whose existence derives from a previous outlay of sunk costs. Following Garnaut and Clunies Ross (1983), a resource project's life might be divided into three phases: exploration, development, and extraction. (One could add fourth and fifth phases, those of processing the extracted ore and of cleanup and shutdown of the mine, though these would not affect the current discussion.) The first two phases will involve substantial investment costs, and in the case of exploration some uncertainty about the size of resource deposit found. At the end of the first phase, exploration costs are sunk and uncertainty about the size of the deposit is substantially resolved. The present value of subsequent expected revenues less development and extraction costs is the quasi-rent from the known deposit. Again, after the second phase development costs have been incurred, and there will be a quasi-rent associated with future expected revenues less extraction costs. An integrated firm will operate so as to maximize its quasi-rents in each phase less its initial outlay, and in so doing will also maximize its overall rents ex ante. By the same token, if different firms are involved in the three phases, overall rent maximization will be achieved if resource property rights are properly priced in going from one phase to another. Thus, the value of a resource discovered by an exploration firm could in principle be sold to a developing firm at a price reflecting expected future quasi-rents.

A resource tax system that aims to be efficient should tax full rents, not quasi-rents. This may be difficult to do if tax is applied only at the extraction stage, since by then only successful resource discoveries will be pursued. The full cost of resource exploitation includes the costs of unsuccessful exploration expenditures as well, and unless these are somehow treated as deductible costs for tax purposes, exploration will be inefficiently low. (The time consistency problem discussed above is precisely the temptation to tax away such quasi-rents). Suppose, for example, that exploration costing \$10 million has a ten percent chance of discovering deposits that can be sold for \$160 million (and extracted costlessly), and ninety percent chance of finding nothing. In the event of success, the quasi-rents of \$160 million cannot be fully taxed away if exploration is to be profitable. Clearly it would not be enough simply to allow exploration costs as a deduction in the event of success, and levy tax of \$150 million, since the possibility of failure means that expected return to exploration would then be negative. The most that can be taken in tax in the event that the project succeeds is \$60 million: the investor then stands a 10 percent chance of earning \$90 million after tax and exploration costs that just offsets the 90 percent chance of simply losing \$10 million.[5] It is

[5] Similarly, the largest tax that could be imposed ex ante (before the outcome of exploration is known), without expected profits becoming negative, is \$6 million, just offsetting expected pre-tax earnings of (0.1)×(160-10) - (0.9)×10 million.

this $60 million that represents rent viewed over the full lifetime of the project, and which the objective of efficient rent taxation should lead policy makers to focus on.

All this points to a resource tax system that recognizes all phases of resource production. The treatment of exploration costs, in particular, is critical—just as the treatment of R&D expenses more generally can be critical to efficient support of innovation.

The prospect of large, persistent rents also creates well-known problems of rent-seeking and corruption: these, however, are not the focus of attention here.[6]

Tax revenue can be substantial, and a primary benefit to the host country

Reflecting the substantial rents to be earned, government revenue from resource activities can be sizable not only absolutely but also as a share of all such revenue: Table 1 documents this for selected resource-rich countries. Access to a relatively efficient revenue source of this kind potentially strengthens the fiscal position, allowing reduced borrowing, increased spending and/or less reliance on more distorting taxes. One would expect, for example, that resource-rich countries would take the benefit in part by making less use of presumably less efficient non-resource tax instruments; Bornhorst, Gupta and Thornton (2008) find that this has indeed been the case for a panel of oil-rich countries.

The importance of resource revenues, especially when concentrated within countries on relatively few fields, has another implication: more systematically than in other areas, tax design is de facto a matter of negotiation between government and investor (and/or of frequent changes to the general regime), rather than of designing some system that is then simply applied uniformly to all. While there may be merits in terms of transparency, and perhaps fairness and credibility too, in having tax rules set an arms-length from the circumstances of particular projects and investors, in practice—and especially for countries with only a few large sources—this will simply not happen.

Tax revenue may not be the only economic benefit from resource projects. Foreign investment is often seen as conveying substantial external benefits to host economies—beyond, that is, the domestic share in the financial returns it yields—in terms, notably, of easing unemployment and developing human capital. Resource investments, however, are highly capital intensive, so that associated employment (especially in upstream activities) can be quite modest, and also relatively low-skilled. Joint ventures are in large part seen as a way to encourage transfer of higher level skills, though there is little evidence on how succesfully

[6] See, for instance, McPherson and MacSearraigh (2007).

Table 1. Receipts from Hydrocarbons and zminerals in Percent of Government Revenue
(average 2000-07, selected countries) 1/

Hydrocarbons		Minerals 2/	
Algeria	72	Botswana (diamonds)	44
Angola	76	Chile (copper)	12
Azerbaijan	59	Guinea (bauxite/alumina)	19
Bahrain	74	Jordan (phosphates)	1
Bolivia	24	Liberia (iron ore, gold)	8
Cameroon	27	Mongolia (copper, gold)	9
Chad	27	Namibia (diamonds)	8
Colombia	10	Peru (Gold, copper, silver)	5
Congo, Republic of	73	Sierra Leone (diamonds, bauxite)	1
Ecuador	25	South Africa (gold, platinum)	2
Equatorial Guinea	77		
Gabon	10		
Indonesia	26		
Iran	65		
Iraq	97		
Kazakhstan	27		
Kuwait	79		
Libya	77		
Mauritania	11		
Mexico	34		
Nigeria	78		
Norway	26		
Oman	83		
Papua New Guinea	21		
Qatar	68		
Russia	22		
São Tomé and Principe	35		
Saudi Arabia	72		
Sudan	50		
Syrian Arab Republic	39		
Timor Leste	70		
Trinidad and Tobago	38		
Turkmenistan	46		
United Arab Emirates	69		
Venezuela	48		
Vietnam	31		
Yemen	72		

Source: IMF staff calculations.
Notes:
1/ Revenue (taken from the *World Economic Outlook)* is 'General government, total revenue and grants' when available (which is in most cases), and 'Central government, total revenue and grants' otherwise.
2/ Principal minerals in brackets.

this has been achieved: the continued dominance of firms based in developed countries suggests perhaps that success has been limited. While encouraging (which does not necessarily mean subsidizing) industrial linkages beyond resource enclaves can clearly be useful, spillovers, in this sense, may be quite limited. And of course they are in some respects adverse, with the risk of significant environmental damage both from the inescapable footprint of extraction activities and accidental oil spills and other damage.

Combined with the prevalence of foreign-ownership, and the sheer scale of government receipts, all this means that tax revenue is likely to be not simply a side-benefit of resource extraction but the core benefit itself. Not entirely unique to resources—much the same is true, for example, of the offshore banking that many developing countries have tried to attract—this makes proper tax design in the host country still more important.

Uncertainty

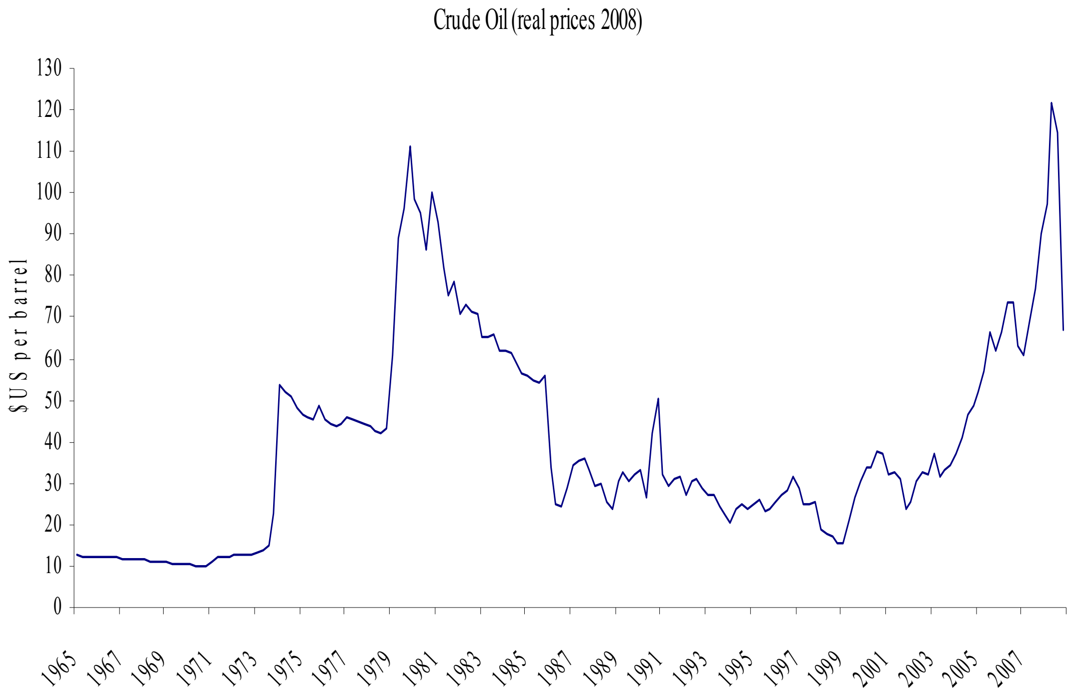
Resource projects are subject to considerable uncertainty at all stages, from exploration through development to extraction and closure. Once again, the same is true in many sectors, not least those (like chemicals) that are intensive in R&D. But the inherent uncertainties and longevity of the production period exacerbate the extent of the challenges.

Geology poses its own uncertainties: How much of the resource will be present, in what quality, how accessibly, and by means of what perhaps as yet undeveloped technology? For multinationals operating a portfolio of projects, or countries endowed with many deposits these idiosyncratic risks may pose little difficulty, as failure in some places is offset by success elsewhere. For countries with just a few possible deposits, however, the uncertainty poses real problems.

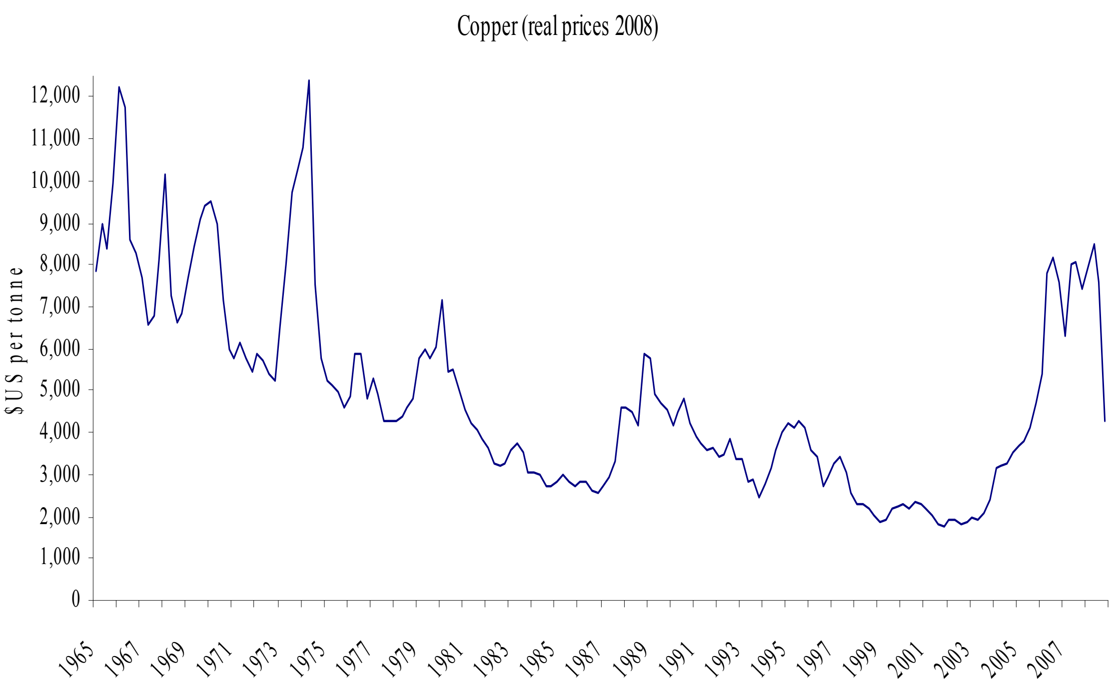
Price uncertainty poses more systemic difficulties, not being naturally diversified in the same way. And the uncertainty and volatility of output prices[7] is indeed one of the most marked features of the sector. Figure 1 illustrates, showing the prices of crude oil, copper and uranium over the last 40 years (20 for uranium). The roller-coaster of the last decade or so epitomizes the difficulty. From around $15 per barrel at the end of 1998, for example, the price of crude oil rose to $112 by the summer of 2008 before falling to $60 at year end.

[7] There is input price uncertainty too, which to some degree parallels that of output prices: key inputs in minerals production, for instance, include chemicals whose price in turn reflects minerals prices, and supplies of specialist equipment, such as oil rigs, may be relatively fixed in the short term.

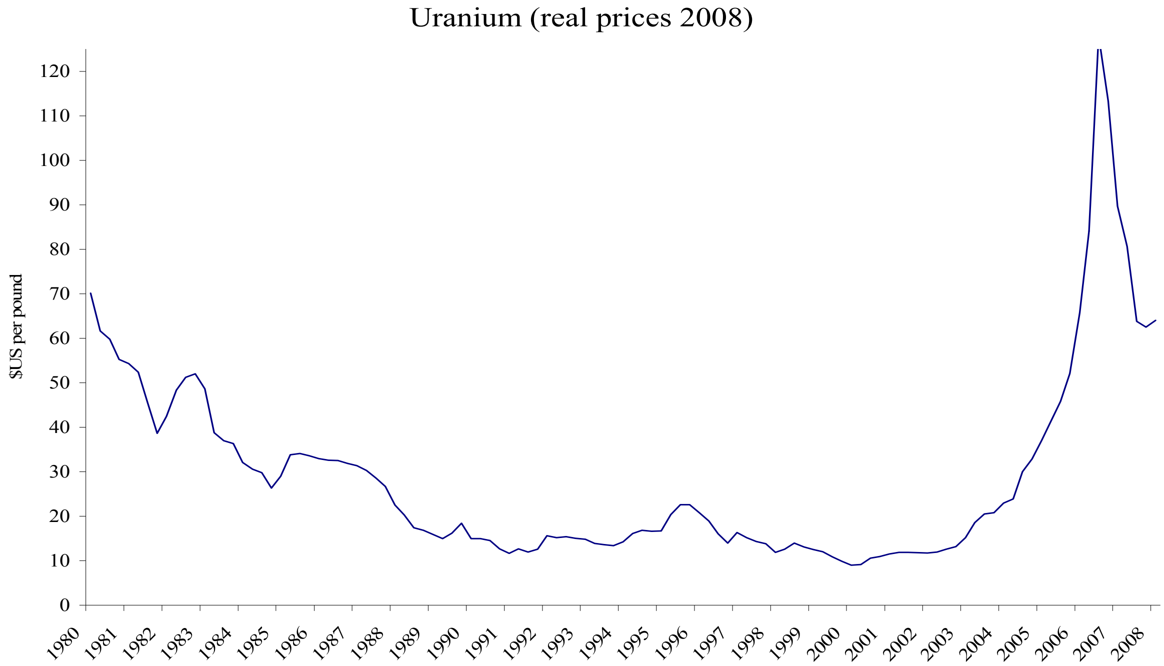
Figure 1: Resource Price Movements



Note: Simple average of Dated Brent, West Texas Intermediate, and the Dubai Fateh, US$ per barrel.



Note: Copper, grade A cathode, LME spot price, CIF European ports, US$ per metric tonne.



Note: Uranium, u3o8 restricted price, Nuexco exchange spot, US$ per pound.

Copper prices also rose to a peak at around the same time, before a marked fall, as did other mineral prices. Developments in the uranium price were particularly spectacular, rising from under $10 per pound at the start of the decade to more than $120 at end 2007, before tumbling to $64 at the end of 2008. These large and in many cases rapid price movements translate into considerable uncertainty and variability in the aggregate rents obtained over the lifetime of a project, and the distinct possibility that total rents will turn out to be negative—with powerful implications for decision-making, and the way in which tax design can affect it. They also strongly impact public debate on the tax treatment of resource activities: widespread talk of windfall taxes and contract renegotiation around mid-2008, for instance, had evaporated by year-end.

In addition to these uncertainties inherent in the economics of resource extraction, there are also many policy uncertainties, some reflecting the time consistency problem, some arising from wider political risks in dealing with potentially unstable regimes, and others from specific policy uncertainties, not least, for oil and other fossil fuels, in relation to evolving policies towards climate change.

Resource activities can entail particular risks for workers and entire communities. With resources often located in remote areas, communities growing up around them may be one-firm towns, exposing workers and their families to risks that they find hard to diversify away.

Governments are often left to assume some responsibility for the hardship felt by resource-dependent communities that fall on tough times.

International considerations

Reflecting the relative scarcity of the technical and managerial skills needed, the development and exploitation of natural resources is commonly undertaken primarily by foreign-owned firms, albeit often in conjunction with state-owned companies (especially in the oil sector) or in joint ventures with domestically-owned companies. Once more this is not unique to the sector, but is so pervasive as to make it especially important for resource tax design. It has several implications.

The most obvious is that since more than one jurisdiction will typically seek to tax any resource project, investors and each government concerned must look to the combined impact of all these taxes, not just those in any single country. This in turn has a number of consequences.

One is that the effective rate of taxation on any project depends not only on the tax system in the host country, but also on tax rules in the home country of the investing firm, the countries in which owners of the investing firm reside, and, perhaps, any countries through which income is routed. It is conventional to focus only on the host country tax system in evaluating tax impacts on projects, but taxation in these other countries can also have a powerful impact on revenues, profitability, and behavior. Of particular importance is the treatment in home countries asserting the right to tax income that has been earned and taxed abroad. Standard corporate and withholding tax payments will generally be creditable against home country liability in such countries, for instance, but royalties will not; and explicit rent taxes may be creditable only if explicit provision for this is made for this in double tax agreements.

Awareness of the interactions between the various tax systems can in turn impact proper tax design. The impact of a host country rent tax on incentives to invest, for instance, depends critically on whether or not such tax payments are available as a credit against the liability of the foreign-owned firm in its home country. And if host countries—which have, de facto and de jure, the first right to tax activities undertaken in their jurisdiction—fail to fully tax the rents on some resource activity, the home government may seek to do so instead. The international nature of resource companies' operations also creates particular opportunities for tax avoidance, and corresponding challenges for national tax administrations—often an inherently unequal contest, given the expertise and funds available to large multinationals relative to domestic tax administrations even in relatively advanced economies. In some respects, these challenges are actually easier in the resource sector than in others. In particular, resource themselves often have well-established world prices that can be used to monitor transfer pricing arrangements within multinationals.[8] This is especially so in relation to oil. But it is not always the case: spot prices for natural gas are limited, for instance (as stressed by Kellas (2009)) and there are no reliable spot prices for ferrochrome and ferromanganese products. Moreover, even when resource prices are observable there remain other avoidance opportunities, notably through using financial arrangements to shift taxable income from high and to low tax jurisdictions. These and other technical aspects of international tax rules as they affect the resource sector are not, however, pursued further here: a full treatment is in Mullins (2009).[9]

The prevalence of foreign ownership may also affect host countries' incentives in tax setting: after-tax profits accruing to foreigners are presumably less valuable socially than are receipts accruing to domestic citizens. They may thus be given relatively little weight in tax design.

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. It is clear enough, for instance, why a country wishing to attract a car factory or the research headquarters of a large software company would not wish to find others offering more attractive tax regimes: the factory or research center might be established elsewhere instead. But a company cannot choose to exploit a gold deposit located in one country by building a mine in another. The potential rents to be earned from the deposit are specific to a particular location, so that standard tax theory would suggest that such rents can be taxed at up to 100 percent without jeopardizing the existence of the project. The puzzle, to which we return below, is to explain why tax competition is as strong in relation to resources as casual inspection suggests it to be.

Asymmetric information

Policy makers will generally be less well-informed of the geological and commercial circumstances at all stages of particular resource projects than are those who undertake the exploration, development and extraction. These asymmetries of information make rent extraction potentially far more difficult than would otherwise be the case, since operators, knowing that it may increase their tax charge, have no direct interest in sharing their superior information with government. They may have an interest in understating the likely stock of the resource, and overstating the difficulty of its extraction. And, even short of outright evasion, they may have a range of devices for understating measured profits in the host

[8] Calder (2009a,b) discusses these and other challenges in administering taxes on the resource sector.

[9] See also Clark (1995).

country once activity is underway, for example through transfer pricing and similar profit-shifting of the type discussed above.

Asymmetries of information of this kind are far from unique to the resource sector, and indeed without them tax design and implementation would be a largely trivial problem (since liability could be directly tied, without risk of distortion, to underlying features determining ability to pay). Policy makers can to some degree mitigate the asymmetry in resource activities by undertaking their own geological surveys and using consultancy services of those with industry-specific expertise. But asymmetries are likely to remain, and to be especially marked in lower income countries that find themselves with limited domestic capacity to match against large and long-established multinationals. The same is true in other sectors too, of course—such as in relation to financial institutions—but the challenges are again are so fundamental to resource activities as to merit special attention.

Market power

Most analyses of resource taxation assume that host governments and investors behave competitively, especially in the sense of taking the world price of the resource concerned as given. But this may not always be so. Host governments may be able to exercise appreciable control over the flow of some resources into the world markets, whether collectively (the most familiar example being OPEC) or, in some cases, individually: the ten largest oil producing countries, for example, account for around 60 percent of world production, and South Africa holds nearly ninety percent of the world's reserves of platinum. Companies may also exercise significant market power: the Potash Corporation of Saskatchewan, for example, produces over 20 percent of the world's potash. Such market power can have several implications.

First, it can change the incentives for tax-setting in both host countries and resource-importing ones. A country that can deploy a rent tax, for instance, would not benefit (in revenue terms) by taxing exports if its production does not affect world prices: because of the distortion that the export tax creates—causing less to be produced than could profitably be sold at world prices—the revenue consequently raised would be less than the rent foregone. If it can affect world prices, however, then some taxation of exports would generally be desirable as a means of raising that world price.[10] By the same token, resource importers have an incentive to impose a tariff if by doing so they can reduce its world price. These incentives for strategic tax-setting are made more complex by the exhaustible nature of natural resources, discussed below, but the broad insights remain: Karp and Newbery (1992),

[10] The same logic applies within federations when one state exports some resource to others: taxation of those exports may not be permissible, but production taxation can serve a similar purpose—as, for instance, with the severance tax on West Virginia coal sold for power generation in other states.

for instance, finds that on this account oil importing countries have an incentive to impose substantial tariffs.

Not least, market power may also provide an additional source of rents for governments to seek to tax. It can also change the impact of standard tax instruments. A royalty imposed on all sales by a group of imperfectly competitive extracting firms, for instance, could cause their profits to *increase*: this is because it would serve, in effect, as a device for achieving a coordinated output reduction that they are unable to achieve by any credible agreement amongst themselves (see, for instance, Stern (1987)).

Project basis

Less commonly remarked, but quite unusual by wider standards, is the possibility and practice of taxing resource sector activities on a project rather than a company basis. One does not think, for example, of taxing a soft drink company separately on its various production plants, or an accounting firm differentially on the profits earned from its various offices. There are exceptions, of course: special incentives are sometimes provided for large projects, and restrictions on company grouping for the corporate income tax are in a broad sense analogous to ring-fencing arrangements in resource taxation. But the nature of resource activities—the inability to switch deposits between projects—lends itself to a project-based approach to tax design and evaluation not found systematically in other areas. Otto et al (2006) argue that mine-by-mine royalty-setting has become less common. Nevertheless, differentiation across projects continues to be found—between onshore and offshore oil projects, for instance and, inherently, in the use of auctioning—and remains an option in a wide range of circumstances.

Exhaustibility

None of the features above is entirely unique to the resource sector. What is unique to non-renewable resources with which we are concerned, is, by definition, the finiteness of potential production. The point should not be taken entirely literally: new resource deposits are discovered,[11] the extent to which deposits are exploited is itself a choice variable, and for many resources known stocks are so large that finiteness is not an immediate concern. (Current coal stocks, for example, are enough for several hundred years, at current usage rates). Nevertheless, the basic distinctive feature remains, and applies both in aggregate and to particular projects: more extraction now means less potential extraction later.

[11] Krautkraemer (1998) notes, for instance, that petroleum reserves increased by more than 10 years of current consumption between 1972 and 1990 even though annual consumption increased very substantially.

This has profound implications for the economics of resource extraction. Four are particularly relevant for tax design (details being spelt out in Box 1):

- The marginal cost to which the marginal benefit from extraction is optimally equated reflects not only the current production cost but the opportunity cost in terms of future extraction foregone (this being the (marginal) Hotelling rent discussed above).

- A resource stock should be depleted in such a way that the shadow price of the resource (that is, the value of an additional unit of the resource stock) rises at the sum of the discount rate and a term reflecting the extent to which extraction becomes more costly as the stock declines. The reason for this is simply that deferring extraction will be worthwhile whenever this leads to a gain in instantaneous welfare, including through any reduction in future extraction costs, that outweighs the discounting of future benefit.

- As a special case of the previous point, if production costs are independent of the remaining stock of the resource, its price would be expected to rise at the rate of interest: the 'Hotelling rule.'

- A higher discount rate is expected (though the point is not theoretically clear-cut) to lead to faster extraction, the intuition being that it increases the financial return from extracting resources early and investing the proceeds.

Empirically, there is substantial evidence that the evolution of resource prices and valuations is not well-described by the simple model that underlies these results: see for example, Krautkraemer (1999), where possible reasons for this (such as the importance of new discoveries) are also discussed. Nevertheless, these relations capture inescapable trade-offs that arise in exploiting established resource stocks and which, as will be seen below, bear on important aspects of tax design.

Box 1. Economics of Resource Extraction—Some Key Results

Denote by $V(S)$ the maximized value of some objective function—whether that of a policy-maker, or of a private investor—conditional on a current resource stock of *S*, and reflecting the expectation of optimal decision making at all future dates. With extraction of *q* giving rise to current benefits of $B(q)$ and costs of $C(q,S)$ (so that, for instance, *C* is decreasing in *S* if extraction becomes more costly as the stock is exhausted), this maximized value is defined recursively as

$$V(S_t) = \max_{q_t}\left\{B(q_t) - C(q_t, S_t) + \frac{1}{1+r}E_t[V(S_{t+1})]\right\}, \tag{1.1}$$

the discount rate being *r* and the expectation (conditional on information at time *t*) reflecting potential future uncertainties, for instance in resource prices. (When *B* is simply revenue from sales of the resource, *V* corresponds to quasi-rent, costs sunk in discovering the stock and readying for its extraction being taken as given). With extraction reducing the available stock (and, by assumption, no new discoveries), so that $S_{t+1} = S_t - q_t$, optimal extraction in period *t* requires (if positive) that

$$B'(q_t) = C_q(q_t, S_t) + \frac{1}{1+r}E_t[V'(S_{t+1})] \ , \tag{1.2}$$

(and is zero if $B(q) < C(q, S_t)$ for all *q*), with derivatives being denoted by primes for functions of a single variable and subscripts for functions of several. This gives the first result highlighted in the text. Tighter implications for the optimal extraction path follow from differentiating in (1.1) with respect to S_t and rearranging to find

$$\frac{E_t[V'(S_{t+1})] - V'(S_t)}{V'(S_t)} = r + \frac{(1+r)C_S(q_t, S_t)}{V'(S_t)} \quad , \tag{1.3}$$

which gives the second. The third follows on taking the special case in which the marginal benefit from extraction is equal to the exogenous world price of the resource, p_t (either because the resource is consumed domestically or, perhaps more plausibly, because the only concern is the net profit earned from the project) and the price is fixed on world markets:[12] supposing further that costs are independent of the stock, (1.4) reduces to the most familiar form of 'Hotelling rule,' with the price of the resource rising at the rate of discount.

The implications of the conditions in (1.2) and (1.3) for current extraction are hard to see, since both involve all future decisions through the marginal valuation term $E[V'(S_{t+1})]$. Combining the two, this can be eliminated to find[13] that along the optimum

$$\frac{E_t[(B'(q_{t+1}) - C_q(q_{t+1}, S_{t+1})] - \{B'(q_t) - C_q(q_t, S_t)\}}{B'(q_t) - C_q(q_t, S_t)} = r + \frac{E_t[C_S(q_{+1}, S_{t+1})]}{B'(q_t) - C_q(q_t, S_t)}, \tag{1.4}$$

so that the net current benefit from extraction is expected to rise at the rate of interest plus a term reflecting the effect of stock depletion on production costs. To see how an increase in the interest rate is likely to affect extraction rates, note first that, with the same total stock of the resource to be exhausted, the extraction paths under a high and a lower interest rate will at some date cross. With q_t, say, the same under both paths (and assuming that $C_S = 0$), it follows from (1.4), given the concavity of net benefit, that q_{t+1} is lower at the higher interest rate; which means—the fourth point in the text—that extraction is more rapid.

[12] Whether extraction will be faster or slower than in this competitive case when the producer has monopoly power—so that marginal benefit in Box 1 becomes downward-sloping marginal revenue—is theoretically indeterminate: see Stiglitz (1976).

[13] This follows on taking the expectation at time *t* of the necessary condition (1.2) for extraction at time *t+1*, combining it with that condition for time *t* and using too the time *t* expectation of the expected change in marginal valuations between *t+1* and *t+2* implied by (1.3).

III. TAX INSTRUMENTS AND THEIR EFFECTS

This section reviews the main tax (and tax-like) instruments that are or might be deployed in the resource sector, and some of the issues that arise in assessing their likely impact on resource operations and government revenue.

A. Key Tax Instruments for the Resource Sector

Reflecting the complexities of governments' objectives and the accumulation of considerable ingenuity in responding to the fiscal challenges posed by the special features of mining and petroleum operations, a wide range of tax instruments is found in the sector, with single projects commonly subject to multiple charges. An exhaustive listing of such taxes would be tedious; the aim here is simply to outline some of the principal design choices that each raises.

Royalties

While the term has come to be used increasing imprecisely,[14] the essential idea of a royalty—also (though now less commonly) referred to as a severance tax—is that of a charge (whether specific or ad valorem) levied directly on the extraction of the resource itself. Such charges are commonly given a legalistic justification, as payment to the resource owner, usually the state (which, outside the United States, almost always has legal title to the resource itself), for the right to take ownership of its property. For this reason, royalties are commonly recorded in the fiscal accounts as non-tax revenues. From the perspective of the investor, of course, it makes little difference whether a payment is called a royalty or a tax: the economic impact is the same. In terms of policy design too, whether one thinks of a royalty as akin to a user fee or as an explicit tax, the determination of its proper level and time path reduces to the same question in optimal pricing.

Royalties can significantly affect extraction decisions (and, through the anticipation of such effects, and their impact on profitability, decisions on exploration and development too). Importantly, this effect of royalties depends not only their current level but on their future levels too: the alternative to extracting now and paying today's royalty is to extract later and pay tomorrow's. What matters is thus not the level of today's royalty, but whether it is higher or lower than the present value of tomorrow's.[15] The extraction path is entirely unaffected, for

[14] The definition of 'royalty' in Otto et al (2006), for example, is extremely broad, including anything that is called a royalty.

[15] To see this, note that for a competitive producer (for whom the marginal benefit of extraction is simply the resource price), payment of royalties θ_t and θ_{t+1} (adding to costs by these amounts) changes the necessary condition (1.4) to

(continued)

instance, if (and only if) the royalty per unit of output rises at the investor's discount rate: for then the present value of the tax payable when some unit of the resource is extracted is the same whenever that extraction takes place.[16] In effect, the tax then functions as a non-distorting charge on the quasi-rents earned by existing projects. Few royalties are specified to grow in this way however, so that the extraction path may be affected. For instance, for a royalty charged as a specific amount (that is, a fixed and unchanging amount per unit of the resource), the incentive is to defer extraction, since the present value charge is lower the later extraction occurs.[17] On the other hand, a royalty charged as an ad valorem amount (that is, as a proportion of sales receipts) will tend to accelerate extraction if the resource price is expected to increase at a pace above the interest rate.

A more commonly expressed concern with royalties is that they may lead to premature closure of operations: social optimality requires that extraction cease once price no longer covers marginal extraction costs, but private operators faced with a royalty will instead end operations when price ceases to cover extraction cost *plus* the royalty. How significant such effects have been in practice is unclear, as Otto et al (2006) note; many mining laws contain provisions, discretionary or otherwise, for royalties to be waived or deferred if they would make extraction unprofitable.

The impact on closure decisions will also depend on the effective incidence of the tax. While the analysis above presumes a single price-taking producer, a royalty levied on all sales of some resource might lead not to a reduction in the price received by the producer but an increase in that paid by the consumer. In this case the main challenge to continued production may come rather from the development of alterative technologies. A prime instance of this is in relation to fossil fuels. The incidence of a uniform carbon tax might then fall largely on consumers, with little impact on extraction paths but potentially significant effects in fostering the development of alternative technologies (Sinn (2007), Strand (2007)).

A further potentially important efficiency loss from royalties arises because they apply only at the extraction phase of resource production. At best, they constitute imperfect taxes on the quasi-rents from successful deposits and take no account of the sunk costs of exploration and site development. Quite apart from whether they tax quasi-rents efficiently (that is, without

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$$\frac{\Delta E[p - c_q]}{p - c_q} = r + (\theta_{t+1} - (1+r)\theta_t)$$

(it being assumed for simplicity that $C_S = 0$).

[16] This observation is due to Burness (1976). The argument here ignores the potential impact of royalties on the shutdown decision, discussed in the next paragraph.

[17] This effect arises it should be noted, even if the specific royalty is indexed to the general price level.

distorting the path of extraction), they will discourage exploration and development since their base is not the entire rent. By the same token, they discourage risky projects by taxing only successful outcomes.

Royalties are not quite ubiquitous in practice—Chile and South Africa, for example, have long had no conventional mining royalties (though they have royalties that are partially profit–related), and nor has Denmark for oil and gas production or the UK (since 2002) for oil—but are very widely applied to resource activities. Their precise form, however, can vary considerably, and hence so too might their impact:

- Ad valorem and specific royalties—even if initially equal in monetary value—can imply different time paths of extraction, as just noted.

- The precise base can also differ: the royalty might be based on the value of ore at the minehead, for example, or on the net smelter return (the value of the processed or refined product net of processing costs), or on the value of exports after 'netback' for transport and other costs. Otto et al (2006) give an example in which (non-profit related) royalties at rates varying between 2.75 and 3.45 percent can imply the same total tax take, depending on exactly how the base is defined.

- These differences can also have behavioral consequences. For instance, a specific tax (rare in practice, outside industrial minerals) on the refined product can distort decisions as to which grade of the resource to extract (because tax paid will be higher for richer ores) when, for instance, one on the crude ore does not (because then tax paid is independent of ore quality).[18]

- Royalty structures can display a wide range of non-linearities: they may increase with the amount extracted and/or the world price of the resource (in the latter case, for example, tending to encourage extraction when prices are expected to increase rapidly), and in some cases have been structured to decrease over time, eventually vanishing.

- Royalties may be levied at the same rate on a range of minerals, or differentiated across them. There is evidently some, perhaps modest, administrative merit in the simplicity of uniform structures—and perhaps political advantage too, in protecting against special pleading. The case for differentiation is less clear. If the royalty on some resource were intended to exercise power in world market, the appropriate rate would vary with demand and supply characteristics, which would be likely to differ across resources. But that is rarely the purpose. If they are serving to bring forward

[18] Conrad and Hool (1991).

tax payments, the rate might appropriately vary with the time profile of output and profits, and the proper differentiation would likely vary as much across deposits as across minerals. The most persuasive argument for differentiation—rationalizing perhaps the higher royalty rate often applied to diamonds—is that the royalty is serving as a rent extraction device. But the scope for distortions makes it a poorly targeted one: if effective rent taxation is in place, the case for differential royalty rates is correspondingly weakened.

- Stretching normal usage of the term, royalties may also be profit-based, in the sense of being levied on revenue less some elements of cost: the ad valorem royalty rate might depend for instance, on the ratio of revenue to sales. Such taxes may apply either in isolation or as part of hybrid in which they are combined with simple output-based schemes, with the latter in effect operating as a minimum tax creditable against the former. Profit-based royalties are perhaps most usefully regarded simply as profit taxes, discussed separately below.

What then might be the proper role of royalties—focusing here on the very simplest form, of charges related to output or its value (and abstracting from quality effects)—in a well-constructed resource tax system?

In some circumstances, royalties may have an essentially corrective role in encouraging efficient utilization. This will be the case, for example if investors discount at an inappropriate rate. If they use too high a discount rate, for example, and so tend to extract too quickly, this can be offset by imposing a royalty that decreases (in present value) sufficiently rapidly.

More subtly, but perhaps no less plausibly, a role for royalties also emerges if—as is almost invariably the case—the extractor has unlimited rights to extract the resource over some finite contract period (and receives no payment for the resource remaining at the end of the period for which it enjoys extraction rights).[19] Attaching no value to any of the resource left in the ground at the end of its contract, the firm will tend to extract too rapidly. In the final period, most clearly, it will simply extract up to the point at which the resource price just covers marginal extraction cost; but this, recalling the first bullet around Box 1, implies excessively fast extraction since it ignores the opportunity cost in terms of future extraction foregone. More generally, given the cost advantage of smoothing production, one would expect extraction to be more than socially optimal throughout the period of the contract, with the extent of this inefficiency rising—because the enterprise cares less about future extraction

[19] Approval of production plans is often required—potentially an implicit royalty—but rarely exercised, it seems (in the activities at issue in this paper), in the direction of preserving future stocks.

opportunities foregone—as the end of the contract period approaches.[20] Correcting this, to ensure an efficient extraction path, requires that the investor face a charge for each unit of extraction equal to the amount by which their marginal valuation of the remaining stock falls short of the appropriate social marginal valuation—which is likely to mean a royalty that increases over time as the end of the contract approaches.[21] The strength of this argument for the use of royalties clearly depends, however, on the length of the investor's horizon. If it has full title to the entire deposit (or can sell the remaining stock when its contract expires) then it will itself recognize the opportunity cost, and no corrective charge is needed to ensure that it fully internalizes this in its own extraction decisions.

In practice, the principal rationale of simple royalties is a pragmatic one, reflecting three potential advantages to the government over profit-based taxes. First, they may be relatively easy to implement. Oil and gas production, for instance, is readily measured by equipment at the wellhead. Measuring the amount or value of other minerals extracted, however, can be less than entirely straightforward. Nevertheless, royalties may be less susceptible to the implementation difficulties that asymmetric information can cause, for example, for rent taxes—a point pursued further in Section IV. Second, royalties yield revenue from the very start of production. Of course, earlier revenues for the government entail higher upfront payments by producers. Such a pattern of revenue flows may be rationalized if governments discount the future more heavily than do producers, an issue also taken up later. It may have political advantages too, in showing that foreign-owned projects are at least paying something to the fisc. Third, royalties may provide a more stable and predictable tax base. But royalties have important disadvantages too, not only in the potential distortion of extraction decisions but also—through being levied only at extraction stage, with no offset for exploration and development costs—in potentially bearing discouragingly heavily on quasi-rents.

[20] This assumes that it is not optimal, from the owner's perspective, to entirely exhaust the resource within the contract period. If it is, then there is no inefficiency from the truncation of the contractor's horizon.

[21] Suppose, for instance (assuming perfect certainty, for simplicity) that the profit-maximizing operator plans not to fully extract the resource during the contract period. Then it will act as if the resource were not exhaustible—the shadow value V' in Box 1 will be zero at all times—and so will simply extract so as to set the net marginal benefit $B' - C_q$ to zero in each period. From the wider social perspective, however exhaustibility does matter, and (1.4) shows that net marginal benefit should increase at the rate of interest (also assuming, for simplicity, that costs are unaffected by the remaining stock). There is thus a corrective role for using royalties to slow extraction by driving pre-tax marginal costs increasingly below marginal benefit; and this, by the argument above, requires a royalty that increases (in present value) over time. (If, on the other hand, the operator chooses to fully extract the resource strictly within the contract period, there is—absent such considerations as a divergence between private and social discount rates—no inefficiency).

Rent taxes

The term 'rent tax' is often used quite loosely in the resource literature. Many taxes will bear in part on rents: export taxes can have this effect, for instance, and this can even be the case, as noted above, of royalties. Resource taxes are often tailored, moreover, in an ad hoc but explicit way intended to reflect the likely extent of rents: by, for instance, charging a higher rate of corporate income tax on onshore than offshore operations. Here, however, we use the term more precisely, to refer to any tax that is intended to extract only rents.

The case for rent taxes reflect three attributes of exhaustible resources, their relative fixity in supply, at least once discovered (generating Hotelling rent), the differing qualities of deposits (generating 'Ricardian rent'[22]), and the notion that somehow property rights to a nation's resources are at least partly owned collectively. One way of exercising these property rights in an efficient way is to rely on the private sector to find, develop, extract, process and market resources and then to tax the rents that accrue. So long as the tax base accurately reflects rents—and assuming perfect certainty for the moment—any tax bearing only on rents, whether proportional, progressive or degressive—will leave private decisions unaffected.[23] Uncertainty, however, significantly complicates matters, as will be seen.

In thinking about the design of taxes on rents, it is useful to consider in turn the tax base and the level and structure of tax rates applied to it.

The choice of base

One way to think about rents is in terms of the conventional notion of economic profit over some interval, say of one year. Economic profit earned during a year is the difference between revenues and imputed costs over that period, all on an accruals basis. In the case of revenues, this is simply accounts receivable. Costs are more difficult. For current costs (materials, rents, labor,…), accounts payable are used. For costs associated with assets, the imputed costs are those associated with holding or using the asset for a year, rather than the costs of acquiring the assets initially. These imputed costs include financing costs (such as interest paid on debt and the required return to equity finance), depreciation or depletion due to use, and capital losses over the period. An annual tax system levied at a constant marginal rate, whose base is economic profits thus defined, would be neutral (that is, would leave investors' decisions unaffected). Intuitively, firms maximize the present value of their

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[22] As exposited in, for instance, Otto et al (2006).

[23] Denote rents over the full lifetime of the project, which may depend on some choice *a* made by the investor, by $V(a)$. Then for any tax function *T* for which average and marginal rates are everywhere less than unity, the value of *a* that maximizes after-tax rents $V(a) - T[V(a)]$ is the same as that which maximizes pre-tax rents.

economic profits, so a proportional tax would simply reduce the objective function proportionately, leaving optimal choice unchanged.

Standard corporate taxes, however, are not taxes on economic profits, and nor are they intended to be. To the extent that they allow interest on debt to be deducted but not the cost of equity financing, they approximate a tax on a firm's equity income, both normal returns to equity and any pure profits or rents. More important, some of the elements that constitute imputed costs are very difficult to measure. For depreciable assets, the rate of depreciation over the year will not be easily observed given the absence of market prices for capital in use. This may not be so much a problem for depletable resources whose use can be readily measured. Greater problems are posed by intangible assets, which, in the case of resource firms, include the value of information learned by exploration expenditures and all long-term assets that have no physical substance, such as development drilling. This makes an economic profit tax base virtually impossible to implement.

Happily, there exist viable alternatives whose tax bases are equivalent to economic profits not period-by-period but rather in present value over the full lifetime of a project. Prominent amongst these are:

- An ***R-based cash flow tax*** (Meade, 1978), commonly referred to in the resource literature as a ***Brown Tax*** (Brown, 1948). This is one charged simply on the producer's cash flow, which in the case of goods-producing firms, consists of all real (as opposed to financial) transactions on a cash basis. The base is thus all revenue from the sale of output less cash outlays for purchases of all inputs, both capital and current. No deduction is allowed for interest or other financial costs: with all investment expenditure immediately expensed, doing so would amount to giving a double deduction. The supplementary charge on petroleum activity in the UK, for example, is in effect an R-based cash flow tax. Note that under a pure R-based cash flow or Brown tax, negative cash flows would give rise to negative tax liabilities that would be fully refunded immediately. Indeed the resource literature generally takes immediate refunding on tax losses as inherent in the Brown tax, and for brevity we shall follow this usage.

- An ***S-based cash flow tax***, also proposed by Meade (1978), is a charge on net distributions to shareholders (dividends less new equity). This includes in the base financial as well as real cash transactions, and so is intended to capture rents from financial services (less of a concern for resource firms).

- An ***Allowance for Corporate Equity*** (ACE) tax base allows firms to deduct not only interest payments on debt but also a notional interest rate on their equity, with the retained earnings element of equity calculated for this purpose using the same depreciation rate as that used to calculate taxable profits. There is now quite extensive experience with the ACE (which is reviewed in Klemm (2007)): Belgium currently operates such a system, as for some time did Croatia, while Italy has employed, and Brazil still does, variants.

- A ***Resource Rent Tax*** (RRT), as proposed by Garnaut and Clunies Ross (1975, 1983), taxes cash flows once their value, cumulated at an appropriately chosen interest rate (this choice being discussed below), becomes positive.[24] Such a scheme is equivalent to an Brown tax with losses not generating refunds but instead carried forward at this same interest rate (provided that, in each case, there is sufficient positive cash flow by the end of the project life to cover losses, or the tax value of any unrelieved losses is fully refunded at the end of the project life—an important consideration that is also discussed below).

Nor are these the only possible forms of rent tax. Indeed all are special cases of a general class of cash flow equivalent tax schemes, for which the present value of the base is equal to the present value of cash flows. The first part of Box 2 describes a class of such present value-equivalent rent taxes, the defining feature being that in each year cash outlays (costs) are added to an account and the firm deducts against tax some fraction of that account, say α_t—different schemes corresponding to different choices of time path for α—along with an interest deduction consisting of the firm's discount rate times the size of the account. Thus cash outlays that are not immediately deducted are carried forward with interest so that the present value of deductions from a given expenditure equals that of the expenditure itself. Hence all such taxes ultimately tax the present value of cash flows; that is, rents. Importantly, the time profile of α_t can be chosen arbitrarily, different choices differing only in the time path of tax payments they imply.[25] This means, for example, that the neutrality of an ACE does not require that depreciation for tax purposes match the true decline in the value of productive assets: 'excessive' depreciation in one period means a reduction in the account carried forward, and consequent increase in future taxes, that in present value has an exactly offsetting effect. In this way these and all other members of this class of rent taxes avoid the difficulty of measuring depreciation that, as noted above, arises under an accruals-based income tax.

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[24] The literature often uses the term resource rent tax quite loosely, to refer to schemes that are in some broad sense are targeted on rent extraction. It is used here more precisely, to refer to the specific Garnaut-Clunies Ross scheme.

[25] There are other ways in which the time profile of government receipts from rents may be varied. If there is a reasonably competitive system for auctioning rights to resource exploration and development, for instance, changes in the tax rate (capitalized in the price bidders will be willing to pay) effectively change the balance between ex post and ex ante rent collection by the government. If the government is less risk averse than resource producers, increasing the share of rents taken ex post will result in relatively more of the risk being borne by the government, and vice versa.

Another set of equivalencies is instructive. Of the schemes just described, the Brown tax and RRT both allow full deduction of current outlays. In this respect they are members of another general class of schemes, differing in the fraction of cumulated net cash flows that are brought into tax. As shown in the second part of Box 2, provided that interest is paid on untaxed cumulated net cash flows at the firm's discount rate, all such schemes are also equivalent in present value to a tax on rents.

Box 2. Present Value-Equivalent Rent Taxes

A wide range of tax structures are equivalent, in present value, to a tax on rents.

Outlays not necessarily immediately deductible

Suppose all cash outlays in year *t*, denoted C_t, are added to an account that will gradually be deductible in the future. Let the size of that account in year *t* be denoted A_t, this being the cumulative sum of past outlays that have not yet been written off. Suppose that in year *t* a proportion α_t of accumulated outlays A_t are written off. The account thus evolves according to $\Delta A_t = C_t - \alpha_t A_t$, where α_t can vary from year to year. Let the tax base in year *t* be $R_t - (\alpha_t + r)A_t$, where R_t represents cash revenues and *r* is the firm's nominal discount rate (assumed constant for simplicity). The present value of the tax base thus defined will be the same as the present value of cash flows themselves, since, using the expression for ΔA_t,

$$\sum_{t=0}^{T}(R_t - (\alpha_t + r)A_t)(1+r)^{-t} = \sum_{t=0}^{T}(R_t - C_t + \Delta A_t - rA_t)(1+r)^{-t} = \sum_{t=0}^{T}(R_t - C_t)(1+r)^{-t}$$

.

(assuming $A_0 = 0$) . In effect, non-deducted cash outlays are carried forward at the rate of discount so that their present value remains unchanged. The value of α_t each year is completely flexible and can be chosen to generate any time pattern for the tax base. The only additional information required to apply this cash-flow-equivalent tax base is the firm's discount rate *r*.

Tax schemes in this class can be thought of as alternative forms of ACE, differing in the effective rate of depreciation. The Brown tax corresponds to the extreme case of immediate expensing, so that $\alpha_t = 1$. An economic profits tax base would set α_t to the true economic depreciation rate of the firm's assets, which is hard to do. In each case, applying a constant proportional tax to the base would be neutral provided that any negative tax liabilities are either fully refunded or carried forward indefinitely with interest (a point discussed further in the text below). A cash flow tax can also be made progressive while maintaining neutrality (under perfect certainty) if the tax rate in each year is increasing in cash flows (rents) accumulated up to that year.

Cash flow-based taxes

There is another (intersecting) class of schemes that are also equivalent to rent taxes in present value, but are based on net cash flows and do not rest on any notion of depreciation. To describe these, denote by B_t the cumulative cash flow, compounded at the discount rate *r*, that has yet to be taxed, and σ_t the proportion of cumulative cash flows that are added to the tax base in period *t*. Then B_t evolves according to $\Delta B_t = R_t - C_t - \sigma_t B_t + rB_t$. The tax base in period *t* is $\sigma_t B_t$, so that the present value of the tax base is:

$$\sum_t \sigma_t B_t (1+r)^{-t} = \sum_r (R_t - C_t - \Delta B_t + rB_t)(1+r)^{-t} = \sum_t (R_t - C_t)(1+r)^{-t}$$

Note the following equivalences:

- If $\sigma_t = 1$, the scheme is the Brown tax, with base $\sigma_t B_t = B_t = R_t - C_t$.
- If $\sigma_t = 0$ for $B_t < 0$ and $\sigma_t = 1$ otherwise, the scheme gives the RRT base. Note that this requires choosing an appropriate discount rate *r*, which the Brown tax does not require.

The key difference between the Brown and RRT bases is the timing of the tax bases: the former presumes immediate loss offsetting, the latter does not.

Note that for the RRT to be fully equivalent to a cash-flow tax in present value terms, negative cumulative cash flows B_t remaining at the end of the project's life must be extinguished. That is, σ_t must then be set to unity. This will be particularly relevant if there are clean-up costs associated with closing down.

More generally, any time profile of tax liabilities can be generated by appropriate choice of a time path of σ_t.

The important differences between these present value-flow equivalent rent taxes is in the time pattern of tax base, and hence of tax payments, that they imply. What then might be the preference of the government over different time profiles? Or might firms themselves be allowed to choose the tax parameters that fix the evolution of the tax base? Note that while the firm should be indifferent across all such schemes—since all imply the same present value of the base, calculated at its own discount rate—the government will value them differently in so far as it has a different discount rate.

In many developing countries, the government may discount the future more heavily than investors (as discussed in section IV below). If there were no restrictions on the timing of tax liabilities, it would then prefer them to be paid entirely upfront, such as by a fixed fee (for example, a signature bid) obtained through auction. Suppose however that the tax base cannot exceed cumulated cash flows and nor can tax payments be negative. In this case, it can be shown—the proof is in Appendix 1—that the best among all possible cash-flow based rent taxes is precisely the RRT. Crucially, however, there are other forms of rent tax—members of the first class of schemes in Box 2—which involve earlier receipt of revenue. One such is the ACE, which yields revenue as soon as revenues exceed depreciation and the required return on capital, which is likely to be well before the date at which they recover, with interest, the full cost of their initial investment.

Also important to stress is that all these schemes, other than the Brown tax, involve using the firm's discount rate to carry forward either costs not yet deducted or cash flows not yet taxed. How to treat such generalized losses is especially important for resource projects, since cash flows are typically negative in the (many) early years, then increase and (if all goes well) become positive in later years before possibly falling off as resources become more difficult to extract and shutdown costs arise. Given tax authorities' evident reluctance to pay refunds to firms making losses, as the Brown tax requires, the alternative—if neutrality is to be retained—is for the government to pay interest on losses carried forward. This too is rarely done in practice for the regular corporate income tax (though Croatia did so, for example), but the proper procedure in a world of perfect certainty—as has so far has been assumed—is in principle straightforward: the firms' discount rate will be the risk-free rate, and it is this that should be used in the schemes set out above. Setting any other rate would destroy the neutrality property of the tax: too low a rate would be expected to lead to under-investment (tax being charged even when no rents are earned), and too high a rate to over-investment.[26]

Uncertainty, however—so central a feature of resource activity—substantially complicates matters, raising two issues. One is the appropriate discount rate for the calibration of schemes of the kind described above; the other is the tax treatment of projects that fail to yield positive rents (which, in a world of perfect certainty, would never be undertaken). The two are closely related.

The question here is deeper than that of how to treat losses that may occur in any single period: as just discussed, these can arise even in a world of perfect certainty. The difficulty, rather, is that in an uncertain world taxing projects that do earn positive rent over their lifetime without providing some tax relief for those that do not creates an asymmetry which results in expected tax rates exceeding the statutory rate. Taxing rents only in good outcomes can destroy the neutrality of a rent tax. Suppose, for example, that a project stands equal chances of earning rent of $20 million and a loss of $10 million, so that expected rent is $5 million: in the absence of tax, the project is thus attractive to investors. But if rents in the event of success are taxed at, say, 60 percent, the expectation is of an after-tax loss of $1 million, and it will not be undertaken.[27]

A central insight into these design challenges posed by uncertainty—the choice of discount rate and treatment of projects earning negative lifetime rents—is provided by a result of

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[26] A simple example illustrates. Consider a project with an initial investment outlay of a that generates a constant stream of cash flows for the life of the project. Let the present value of those cash flows to the firm be some concave function $v(a)$, so that project rents are $v(a)-a$. If the tax is based on rent calculated using a discount rate different from the firm's, then (taking the simple case in which future cash flows are the same in each period) the present value of tax liabilities can be written $T(\mu v(a)-a)$, where μ is greater (or less) than one as the discount rate is lower (or higher) than the firm's discount rate. (The potential nonlineariy of T allows for the possibility of progressivity, discussed further below). Maximizing after-tax rents $v(a)-a-T(\mu v(a)-a)$ then leads to less (more) investment than in the absence of tax as μ is higher (lower) than unity; that is, as the discount rate used in calibrating the tax system is lower (higher) than the firm's.

[27] Ball and Bowers (1983) pursue the nature of this distortion further for an RRT bearing only on positive rents, noting that it is equivalent to a call option taken by the government on the wealth created by a resource project, with exercise price equal to the cumulative investment in it. The analogy implies, for instance, that just as the value of an option increases with the riskiness of the underlying asset so the government's expected tax claim—and hence the discouragement to investment—is greater, all else equal, for riskier projects.

Bond and Devereux (1995, 2003). They show, for a class of cash flow-equivalent taxes, that if tax is fully refundable in the event that the firm ceases operations—corresponding in the resource context to projects that fail to earn a positive lifetime rent—then it is the risk-free-rate that should be used in order to preserve neutrality. Intuitively, if the firm is perfectly certain that it will achieve full loss offset in the future then it will value the corresponding tax refunds at the risk-free rate; carrying losses forward at the risk-free rate thus assures their equivalence in present value to immediate refund. Identifying a risk-free rate in practice is problematic, of course. But this result is nevertheless of considerable practical importance for designing any of the present-value equivalent rent taxes described above (other than the Brown tax, which involves no carrying forward), since it implies that the proper interest rate need not be tailored to the differing circumstances of different firms or projects. Garnaut and Clunies Ross (1983) argue, for instance, that the 'supply price of investment' is likely to vary across firms and projects, so that applying a single threshold rate under an RRT must lead to the kind of inefficiency noted above, a disadvantage not shared by the Brown tax. But this argument has much less force in light of the Bond-Devereux result that discounting in a cash-flow equivalent tax system should be at a risk-free rate, since this would in principle be the same for all firms and projects.

Sovereign risk, however, provides an important caveat to the Bond-Devereux argument. If commitment or other problems mean that the investor is not perfectly sure that cumulated tax credits will be made good, at an unchanging tax rate, they will wish to take account of that in the discount rate applied in valuing future tax reliefs. Applying a risk-free rate to carry-forwards will be insufficient to compensate the firm for waiting: from the perspective of the firm, the expected tax base will exceed expected rents, and investment will be discouraged.

In terms of practicability, any of these present value-equivalent rent taxes would seem much easier to implement than a tax on annual economic profit.[28] They either dispense altogether with the need to specify depreciation rates, for instance, or make the rate irrelevant; and the cumulation that they typically involve does not, in principle, require record-keeping over long periods, since all relevant past information is summarized in an account carried forward from the previous period. Nevertheless, these rent taxes are not without their difficulty. But they are not perfect. Unlike an annual tax on economic profit, for instance, they are neutral only if they are expected to be levied at a constant rate over time: if not, firms will have an incentive to alter their real decisions so that the annual base is lower in years when the tax rate is lower.[29] Thus a present value equivalent rent tax is neutral only if firms believe the government is committed to a constant tax rate into the future, which may be hard for the government to do credibly given the volatility of resource prices. These taxes are also not

[28] Elsewhere in this volume, Calder (2009a,b) and Land (2009) discuss implementation issues more fully.

[29] See Sandmo (1979).

entirely avoidance-proof (though the same is also true of standard income taxes). For example, the distinction between labor income and profits may be opaque for owner-managed firms, and vertically-integrated resource firms may be able to reduce their liability by using transfer pricing on intra-firm transactions for upstream use to deflate their resource revenues.[30] The implications of these and other opportunities for firms to exploit their superior information to understate the base of a rent tax are discussed in Section IV.

Designing and implementing rent taxes is thus not straightforward. What is important to recognize, however, is that there are many ways in which one can set about doing this: the choice is much wider than that between a Brown tax and an RRT: an ACE, for example, avoids both the refunds associated with the former and the delay in government receipts associated with the latter. Indeed there has been increasing practical interest in rent taxation design in relation to business activities in general, much of it focused on the ACE or similar schemes. The present is a time of experimentation in the structure of the corporate income tax, and many of these experiments have been in the direction of targeting the tax more directly on rents.[31]

Tax rates and the pursuit of progressivity

There is relatively little discussion in the literature of the appropriate rate at which rent taxes should be set, as Lund (2009) stresses. No doubt this is largely because efficiency concerns give the simple prescription of taxing rents as heavily as possible. The issue then becomes that of identifying features that prevent their being taxed at (close to) 100 percent. One such is the importance of distinguishing rents from quasi-rents, as discussed above, and avoiding taxing the latter so heavily as to discourage future exploration and development. This suggests, interestingly, that quasi-rents at the extraction stage will be taxed more heavily in countries that face either very high or very low chances of future discovery: in the former case, there is little need to moderate tax charged in order to provide relief for unsuccessful exploration; in the latter, the prospect of discouraging future exploration is of little concern. A second potential consideration is a perceived need to broadly match the tax treatment available in other countries, and a third is the possibility that asymmetries of information may prevent perfect implementation of rent taxes: both of these issues are considered in Section IV.

Putting aside then the simple prescription of taxing all rents at 100 percent, the issue also arises as to the appropriate rate structure for a tax on rents. The simplest tax is a constant

[30] More generally, this raises the issue of what should be the limits of resource activities for the purposes of taxing rents. To eliminate such transfer proving possibilities, these need to extend at least to the processing stage given that different qualities of resource will fetch different values up to that stage.

[31] Tilton (2004, p.146) argues that “rarely do those advocating the taxation of mining rents extend their proposal to other rents.” To the contrary, much of the focus of recent corporate tax reform has been focused precisely on achieving more effective rent taxation: see, for example, Auerbach, Devereux and Simpson (2008).

proportional one, with the same rate applying in all years. All cash flow equivalent tax systems will be in this case be neutral: a proportional tax on cash flows in all periods is equivalent to a proportional tax on the present value of rents. Such a tax remains nondistorting, moreover, in the present of uncertainty, so long as investors are risk-neutral[32] (meaning that they look only to their expected return, not to the full distribution of possible outcomes).[33]

The suggestion is sometimes made, however, to subject the cumulative rents V to some tax $T(V)$ that is progressive in the sense that the average tax rate $T(V)/V$ increases with V. There are many ways in which this could be done.[34] The best known and most influential proposal for progressive taxation of lifetime project earnings in the resource context, is that of Garnaut and Clunies Ross (1975), who envisage a progressive variant of the simple RRT described above. This adds to the single threshold rate of return a second (and maybe more) higher rate above which some additional tax applies. The wide range of rent taxes characterized in Box 2—other than the Brown tax, which involves no cumulation—could be made progressive in essentially the same way. Pioneered in Papua New Guinea, Land (1995) lists nine countries as having such schemes; several more have adopted one since.

While there is thus no difficulty of principle in levying a progressive rent tax, it is not obvious why one might want to do so. There is generally no compelling equity reason, since—even in so far as they accrue to domestic residents (fairness among foreigners presumably being of no concern)—a claim to high rents is neither necessary for sufficient for high income at personal level. A more subtle rationale, offered by Garnaut and Clunies Ross (1983), is that the use of multiple threshold rates, accompanied by a lower starting marginal tax rate (and with subsequently higher marginal rates recouping any consequent revenue loss), may mitigate the risk of distorting decisions by applying a single but wrongly-chosen threshold rate. The stronger, however, is the case for using a risk-free rate in the basic RRT, discussed above, the less force this consideration has. An alternative rationale for some progressivity may be found in political economy considerations: this is pursued later.

[32] Maximizing the expected value of after-tax profit $(1-t)E[V(a)]$ requires maximizing the expected value of pre-tax profit $E[V(a)]$, and so leads to the same decisions as in the absence of tax.

[33] Risk-neutrality is assumed throughout the discussion of uncertainty in the text (perhaps reflecting effective diversification by investors). This is a significant assumption. For a risk-averse investor, for example, a proportional tax, with full loss offset, makes riskier assets strictly *more* attractive since it unambiguously reduces the dispersion of possible outcomes. The qualifications that risk aversion implies for the discussion below are qualitatively straightforward.

[34] Angola, for instance, levies an annual tax that increases with the realized internal rate of return.

Against any benefits of progressivity, in any case, must be weighed a clear disadvantage. This is that—unlike a proportional tax—in the presence of uncertainty a progressive tax is distortionary even if investors are risk-neutral. With an increasing marginal tax rate, rents in favorable states of nature will bear a higher tax than those in unfavorable states, so discriminating against risky investments (as Garnaut and Clunies Ross (1979) themselves stress).[35] Given too the additional burden of administration and compliance implied—and leaving aside potential political economy considerations taken up in Section IV—there is room for doubt as to whether there are any real advantages from taxing cumulative rents progressively.

Sector-specific profit taxes

Resource operations may also be subject to charges that are based on some notion of profit but without such a set of allowances as to make the tax one on rents. These are commonly designed, moreover, to be progressive in a sense that the rate applied to such profits increases with their level.

This is the case for several of the 'profit-based royalty' schemes referred to above. Otto et al (2006) give the example, for instance, of a scheme in Ghana by which the royalty rate is piecewise linear, with a marginal rate that increases with the ratio of the operating margin to sales. This, it is easily seen, is simply equivalent to a progressive tax on operating profit The scheme long applied to gold mining operations in South Africa is also a member of the class of schemes,[36] but with a continuously varying marginal tax rate and applying only on earnings in excess of some (within-period) return. The impact of such arrangements can

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[35] To see this, suppose that in the absence of tax one project generates perfectly certain rents of $\overline{V}$ while a second has a stochastic return V with expected value of $\overline{V}$. By Jensen's inequality, if T is convex, $E[V - T(V)] < E[V] - T(E[V])$; for convex T, progressive taxation thus changes indifference between the two projects into a strict preference for the safer one.

[36] This scheme (which dates back to 1918 and is also used by Botswana, Uganda and Zambia (in varying forms), and, until recently, in Namibia) charges tax on profits at a rate T that depends on the ratio of taxable income from mining to mining revenues (in percent), m, according to

$$T(m) = \max\left\{0, \tau\left(1 - \frac{\rho}{m}\right)\right\}$$

where τ and ρ are parameters: the latter is the rate of return above which tax is payable (earnings below this are in the tax-free 'tunnel') and the former is the tax rate towards which tax payable increases as m rises. The claim in the next sentence follows on noting that, writing $m = \pi / R$, where π denotes profit and R revenue, this becomes

$$T(m)\pi = \max\{0, \tau\pi - \rho R\}.$$

sometimes be opaque: the South African scheme, for instance, is equivalent (for a taxpaying operation) to a proportional tax on profits combined with a subsidy to extraction.

Production sharing

Under production sharing agreements (PSAs)—commonplace in oil and gas, though less so in mining (and described in detail in Nakhle (2009))—the share of 'profit oil' (the profit that remains after 'cost oil' has been taken to cover the contractors' cost) corresponds to a proportionate tax on profits. (Or rather, and the difference may matter, to a tax on whatever 'profit' is defined to be for this purpose: if borrowing costs are not to be covered from cost oil, for example, and investment spending is immediately covered, the charge on profit oil is in effect an R-based cash flow tax). Indeed the similarity between government profit oil and explicit taxation is sometimes recognized by providing for the former to cover the contractors' liability to corporate tax.

Other features of PSAs also replicate possible tax arrangements. Limits on the recovery of cost oil, for instance—allowing only up to some percent of cost to be met from sales proceeds—function in effect as an implicit royalty.

Equity participation

Government may also take direct ownership in resource activities (beyond its ownership of the resource itself), especially at the development stage. This can and does take a variety of forms, in each case—short of a fully paid-up equity share on commercial terms—being equivalent to some tax arrangement in terms of the payments to and from government that it implies: a comprehensive account is in Daniel (1995). For example:

- If the government simply acquires and maintains an equity holding free of charge,[37] it in effect levies a dividend tax at a rate equal to its proportional holding.[38]

- Under carried interest arrangements, the state acquires equity from its allocated share of profits, this payment being inclusive of an interest charge. Since this arrangement has positive net present value to the government only to the extent that the rate of return ultimately earned on its equity exceeds the interest rate charged on its contribution, this is equivalent[39] to an RRT on returns in excess of that interest rate.

[37] The common term 'free equity' can be something of a misnomer, as Conrad, Shalizi and Syme (1990) note: the government, after all, contributes the resource itself.

[38] If it were to subscribe at cost to new equity issues, the equivalence would be with an S-based cash flow tax.

[39] Here, as in other of these equivalencies, it is assumed that there are no other taxes in place; with a corporate income tax also imposed, for example, the implicit base will differ from that of an RRT.

These and other revenue equivalences for PSAs and equity participation do not imply, of course, that these equivalences are complete. This is so not only in terms of the impact of state participation on the efficiency and transparency of government operations but also in more narrow revenue terms. An ownership stake may allow the government to exert direct (perhaps implicit) influence on the extent of tax avoidance activities, for example, and help overcome problems of asymmetric information that may constrain fully arms-length tax design. Government equity participation (even on commercial terms) might also improve efficiency by mitigating political risk: go the extent that the government has a stake in ownership, its temptation to confiscate rents ex post recedes (Garnaut and Clunies Ross, 1983)). As discussed in McPherson (2008), however, there can be severe downsides to having state companies act as fiscal agents.

Auctions[40]

Auctions serve two distinct roles as elements of resource taxation regimes. They allocate rights to exploit natural resources among potential producers, and they generate revenues ex ante for the state. Arguably, the former is at least as important as the latter, given that revenues can be raised by other and complementary methods. These two elements—efficiency and revenue-raising—are also pre-occupations of auction theory and design.

Producers to exploit natural resources can be selected in various ways.[41] Simple rationing schemes (such as first-come-first-served) might be used, as in the case where prospectors can freely stake claims in large geographical areas. There is no guarantee that the most efficient exploration producers will emerge in this case. Still, once discoveries are made, those making them can maximize rents by selling rights to exploit the deposit to more efficient producers. More relevant is the case in which substantial property tracts must be assigned to larger, vertically integrated producers. In this case, simple rationing schemes might be expected to lead to inefficient outcomes. A more sophisticated mechanism is for the government to allocate rights on the basis of technically supported applications: so-called 'beauty contests.' Provided governments are sufficiently well-informed to choose among applicants, and are free from capture, political influence and corruption—these are big 'if's—more efficient producers can be sorted out from less efficient ones. To the extent that applications for resource rights contain monetary bids and are made independently by several producers, they are effectively like either bonus bid auctions or royalty rate auctions (depending on whether the bid consists of a single sum for the right to extract or a payment per unit of extraction).

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[40] The treatment of auctions here is brief: see Cramton (2009) elsewhere in this volume.

[41] It is assumed here that property rights are defined and enforced. If not, a form of tragedy of the commons occurs, with, at a minimum, a tendency to over-spend on exploration and at worst conflict over the exploitation of discovered resource deposits: see Collier and Venables (2008).

Using auctions explicitly has the advantage that in addition to selecting producers, they also generate revenues. Well-designed auctions should in the right circumstances both select producers efficiently and generate the most revenue for the government.

Auctions can be conducted in a variety of ways. The 'revenue equivalence' theorem of auction theory shows that the leading candidate are in some circumstances equivalent—but, as Cramton (2009) makes clear, the conditions required are stringent. What form of auction maximizes the governments expected revenue then depends on such considerations as the nature of bidders' preferences and the characteristics of the objects being auctioned.

The preferences reflected in auctions will be of the 'common-value' type if the value of a natural resource deposit is independent of others held, though different producers may have different information about that value depending on what they have learned from prior technical investigation. More generally, however, the value of one block may be affected by owning others, given complementariness or substitutability in exploration or exploitation. In these circumstances, as Cramton (2009) outlines, ascending auctions (that is, those in which successive bids must be increasing in value) that simultaneously involve many blocks allow for 'price discovery' in the sense of enabling bidders to learn something about the information others might have, and allows for interlinkages between packages of blocks of resources. But ascending auctions can have disadvantages. Observation of bids might lead to opportunities for signaling that allow firms to collude.[42] This problem can be avoided by a sealed bid procedure, though at the cost of eliminating information transmission altogether. More generally, there may be too few participants in auctions because of the costs of entry and the knowledge that the chances of winning might be low for less efficient bidders. And, the winner's curse (the tendency to bid cautiously when the true value of the item is uncertain, given the danger that the winner has over-estimated its value) can lead to understatement of expected values.

Importantly, many of the potential problems with alternative auction mechanisms may well result in too little revenue being generated for the government rather than in the wrong producers being chosen. So long as the government is able to obtain revenue ex post by other taxation measures (credibly committed to prior to the auction), revenue shortfalls from auctions can be less important than selecting the most efficient producers who will generate the highest future rents. This points too to the importance of selecting the bid variables: including an element of royalty bids—or bids on profit tax rates—can provide some assurance against unduly low bonus bids. Such structuring may also help overcome what may have been a significant obstacle to the use of auctions in many developing countries (they remain particularly rare in relation to minerals): the possibility that bonus bids will be

[42] Klemperer (2004).

depressed by the government's inability to commit not to levy additional charges in the future.

Beyond the auction mechanism itself, a number of details are important to auction design. The objects to be auctioned must be defined. Given that resource properties may cover large areas, these may be divided into blocks of chosen sizes. A larger block size will internalize more information from exploration, but might also limit the number of participants in the auction because of scale. The terms of the property rights must be specified including the time horizon, as well as obligations with respect to environmental costs and disposal of waste after the resource is exhausted. There may be contractual obligations imposed on the government as well, such as the provision of infrastructure, the regulatory regime, and even the future tax regime. Indeed, this might be one potential way of enhancing commitment and thereby mitigating the time-consistency problem. However, it would be difficult to make commitment absolute, since one cannot preclude government legislation overriding tax rate obligations.

Other sector-specific charges

Resource operations may also be subject to a range of charges not applied more generally. These may include:

- Bonuses paid to the government at various stages in project development, such as on signature of contracts or licenses, discovery, or when production reaches some level —serving in part to bring forward revenue receipts and shift risk to the contractor. These can be for substantial amounts: Nakhle (2009) cites a signature bonus of $1 billion per block of 4,100 km^2 in Angola.

- Export taxes, which can serve a variety of purposes: as a blunt alternative to income taxation when administrative weaknesses mean that this cannot be imposed directly; to restrict the world supply, and hence raise the world price, of resources for which the country has a considerable market share; and/or to encourage domestic processing activities. These have become less important over the years, in part reflecting greater use of better-targeted tax instruments and, perhaps, increased skepticism as to the effectiveness of tax incentives for domestic processing.

- Charges closer to user fees or corrective taxes, such as rental payments for surface rights needed for extraction, or the taxation implicit in requirements to set aside reserves to cover eventual shut down costs.

- The requirement (perhaps implicit) to provide infrastructure.[43] This is tantamount to earmarking tax revenues, which can create costly inflexibility in the allocation of public spending. The potential advantage of earmarking, on the other hand—stressed by Collier (2009) in discussing recent experiences in Africa, and formalized by Brett and Keen (2000)—is that it can limit politicians' ability to divert revenue to their own purposes (though they may also prove adept in turning spending to their own interests).

Standard taxes, as applied to the resource sector

Resource companies will typically also be subject to taxes of general applicability, though some special issues arise (even leaving aside the international tax aspects discussed in Mullins (2009)):

Corporate income tax

The corporate income tax (CIT) applied to businesses in general is commonly also applied to resource firms in particular, though often with particular provisions relating to the tax base.

One such—a project-based approach along the lines raised at the outset—is the potential *ring-fencing* of operations that are analogous to the restrictions on grouping for CIT purposes but applied at project rather than company level. These restrictions in effect expand the tax base by limiting the use that can be made of losses (an especially important concern in the resource sector given the heavy upfront investment and long lead times). They may also have some merit in easing barriers to new entry that might otherwise arise from the ability of established firms to set off the losses at start-up against earnings from established activities. Efficiency, however, argues against ring-fencing: as stressed above, failure to provide relief for losses—especially in a sector marked by such large costs and long pre-production periods as are resources—runs the risk of creating serious distortions. Thus the better response to any entry barriers is to improve loss-offset arrangements, not limit them. Nevertheless, ring-fencing is likely to appeal to cash-strapped governments, even though they may also be vulnerable to transfer pricing and other profit shifting devices.

Another is the possibility of providing *depletion allowances* reflecting (sometimes in a rough-and-ready way) the reduction in the value of resource stocks implied by their extraction—analogous to depreciation allowances for produced assets. That analogy also stresses that, just as deprecation allowances acknowledge spending to acquire assets, so depletion allowances are appropriate within the logic of an annual income tax only to the extent that payment has been made for the right to extract, and that payment has not already

[43] Daniel (1995) explores the analogy between spending requirements of this type and explicit tax measures.

been deductible from taxes: otherwise, allowing depletion is in effect a subsidy to extraction, equivalent to a negative royalty.[44] And in a cash flow framework, expenditure on acquiring such rights would simply be expensed, like any other investment, with no subsequent tax recognition needed.

The impact of other taxes may also depend on their treatment under the CIT. One set of issues concerns the availability of foreign tax credits, which, as discussed in Mullins (2008) typically calls for sequencing tax charges so as to maximize, within a given total tax payment, corporate tax liability (crediting the CIT against others rather than vice versa). Interactions with the CIT can also be important when the various taxes accrue to different jurisdictions. Allowing royalties to be deductible against the corporate tax (reflecting the perception of them as in effect a cost of production), for instance, is structurally irrelevant in that the same level of aggregate payment could be achieved if they were not deductible simply by setting the royalty at an appropriately lower rate.[45] If, however—as in Canada, for instance—the royalty accrues to provinces but CIT in large part to the federal government, the incentives in tax-setting can be quite different: provinces have an incentive to set higher royalty rates than they otherwise would, since the cost to the taxpayer of any additional revenues this raises is in part offset by a reduction in federal CIT revenue.

Resource activities may also be differentially treated in terms of the CIT rate applied, a higher rate being a simple but blunt device for rent extraction, as stressed by Garnaut and Clunies Ross (1983). Egypt, Norway, and the United Kingdom, for example, apply a differentially high rate of CIT to some resource activities.[46] The principal downside to this—other than the CIT generally not being precisely targeted as a rent tax—is the risk of profit-shifting created by any differentiation in statutory CIT rates.[47]

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[44] Ad valorem or specific, depending on whether the allowance is related to the value or the volume of extraction: see Conrad and Hool (1981). The Technical Committee on Business Taxation in Canada (Department of Finance, 1998) documented that excessive deductions for resource depletion resulted in marginal effective tax rates substantially lower in resource industries than in other industries.

[45] With an ad valorem royalty at rate θ deductible against a CIT levied at rate τ, the effective marginal tax rate on an additional dollar of sales is $\tau + \theta - \tau\theta$; which is exactly as it would be if there no deductibility but the royalty rate were instead $(1-\tau)\theta$.

[46] Norway applies a special rate of 50 percent in addition to the standard 28 percent, while (since 2007) the UK has levied CIT on the continental shelf at 30 percent rather than the standard 28 percent. Both countries provide some uplift for capital expenditures—that is, allow deduction of more than 100 percent—against this higher corporate tax rate.

[47] Interestingly, there is some evidence that resource-rich countries tend to levy higher general rates of CIT than do others: Keen and Mansour (2008) suggest this to be the case, for instance, in sub-Saharan Africa. This is as one would expect if resource rents were relatively immobile and there were a commitment to uniform CIT treatment across sectors.

Import duties[48]

Where tariffs on imported equipment might be problematic—and the trend to lower tariff rates over the last twenty years or so has made this less common than formerly—arrangements are often made to exempt large resource projects. There is indeed good reason for this. Since there is rarely domestic production of these capital goods to protect, the main purpose that such tariffs can serve is simple revenue-raising; but while they succeed in doing so early in a project's lifetime (even before royalties are payable), the same can be achieved by other devices, such as bonus payments, that can be better tailored to the likely overall return to the project.

VAT

Intended as a tax on final domestic consumption, the VAT should in principle have little impact on resource operations, which are commonly largely for export. But that export-orientation itself, combined with heavy upfront costs and long lead times, pose particular problems: with little if any output VAT on domestic sales, relief for VAT charged on inputs cannot be obtained by crediting it against that liability but must come from refunds paid by the domestic tax authorities. And many developing countries have found it hard to pay such refunds in a timely manner[49]—in which case the input VAT 'sticks', raising input costs and serving as an implicit export tax.

The best response is of course to improve the operation of the refund system. Short of that, however, one possibility is to zero-rate purchases by resource operations, at least in their early years (when the problem is most acute, though it is likely to remain throughout the project lifetime). Applied to both domestic purchases and imports, this preserves trade neutrality, but zero-rating 'indirect exporters' in this way creates further problems in the need to ensure that supplies are not then inappropriately also made to the domestic market. In many cases the zero-rating (or, what achieves the same effect, deferral of tax due on import until the first regular inland payment[50]) is for this reason restricted to imports and—to avoid an unacceptable pro-import bias—to large capital goods unlikely to be produced domestically. This still leaves the risk of de facto input taxation, however, on other items, such as the purchase of services.

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[48] Grote (2009) discusses customs and VAT issues for the resource sector in more detail.

[49] Ebrill et al (2001) and Harrison and Krelove (2005) discuss the refund problem and possible solutions..

[50] So that tax becomes due not at import but at precisely the same time as an offsetting credit can be claimed.

B. Effective Tax Rates and the Evaluation of Resource Tax Regimes

Understanding the impact of these various tax instruments on government revenues and on firms' profitability and decision-making is not straightforward: details of tax base matter as much, if not more, than rates; and, as with royalties, there can be complex intertemporal dimensions to consider. These difficulties are compounded when several taxes are applied, with the interactions between them then playing a potentially important role (the impact of royalty payments, for example, being dampened if they are deductible against profits-based taxation). To evaluate and compare alternative resource tax regimes, much effort has gone into developing notions of 'effective' tax rates, intended to provide simple summary indicators of likely tax impacts on resource activities. Daniel et al (2009) provide an exhaustive account and illustration of these methods: here we simply review some the over-arching conceptual issues.

The desire to evaluate and compare tax regimes arises outside the resource sector, of course, and there is a well-established methodology for effective rate calculations with non-resource industries in mind. To a large degree, however, these two lines of work on effective tax rates have developed independently, to the detriment of each: the resource tax literature has been perhaps less rigorous in basing effective rate measures on fully formulated views of firms' optimization decisions, and the wider public finance approach has to a large degree neglected the features that loom large in the resource sector but are also present more widely, such as long gestation periods before initial investment payoff, pervasive uncertainty—and the possibility that projects will simply never be profitable.

There are broadly two types of forward-looking effective tax rate:[51]

- ***The average effective tax rate*** (AETR) is simply the proportion of the present value of the income generated by some hypothetical project that is taken in tax[52]—it is what resource economists tend to call the 'tax take'—and unity minus the AETR is the proportion of the present value of income that accrues to the company). Importantly, the AETR can be calculated at various points in a projects' lifetime: the most common is after discovery has been made, though it is conceptually straightforward (as described in Daniel et al (2009)) to calculate an effective tax rate prior to exploration. Some aspects of detail in these calculations are less than clear-cut. One issue is the choice of discount rate (which may differ, of course, when the tax take is

[51] 'Forward looking' effective tax rates are those based on projections of future profits and interest rates. 'Backward looking' effective rates are based on realized profits and tax payments for firms and industries. (On the latter, see Feldstein, Dicks-Mireaux and Poterba (1993)).

[52] This differs somewhat from the widely-cited formulation of the AETR in Devereux and Griffith (2003), who—as they discuss in detail—prefer to calibrate the AETR by using the pre-tax return, rather than rents, in the denominator (to avoid the complications that arise in handling marginal projects, for which rent is zero).

viewed from perspective of government and of company): a point discussed further in Section IV below. This is closely related to wider questions related to the treatment of uncertainty. One approach, dispensing altogether with the attempt to provide a single summary statistic, is to describe the distribution of the present value of tax payments—or key aspects of it, such as the probability of failing to meet some particular rate of return—as it varies with the resource price or other underlying source of uncertainty.[53]

- ***Marginal effective tax rates*** (METRs) are intended to capture the extent to which the tax system distorts firms' decision making by in effect raising the marginal cost of various actions. They measure the proportion of the pre-tax return on an activity which leaves the firm just breaking even that goes to the government, so capturing the size of the tax distortion to that decision. Three dimensions of behavior in the resource sector are of particular interest in this respect: spending on exploration; capital investment in developing identified deposits (sinking mines, putting oil rigs in place, and so on); and extraction. In each case, embedding in a simple extension of the model of firm decisions set out in Box 1 above a fairly detailed description of the tax system of interest enables one to derive tax wedges that describe the extent to which the tax system raises the marginal cost (given the company's optimal response) of exploring, investing and extracting: Box 3 elaborates.[54] Amongst these METRs, the non-resource literature has focused almost exclusively on that on investment, the other dimensions of decision-making being less paramount in other industries; in the resource sector, however, this is arguably one of the less important dimensions, with limited opportunities for substitution between capital and other factors in developing deposits, and those capital requirements then largely dictated by the extent of the resource believed to be available. Although less familiar, the notion of an METR for exploration is straightforward, capturing the extent to which the marginal cost of the exploration that companies will undertake falls short (or exceeds) the expected return from the discovery of new sources (suggesting a greater (or lesser) extent of spending on exploration): in the absence of taxation, the two would be equated. The METR on extraction is more subtle, reflecting the intertemporal considerations discussed earlier.

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[53] An early application is in Conrad, Shalizi and Syme (1990).

[54] The original formulation is in Boadway, Bruce, McKenzie and Mintz (1987). A recent application—focusing in particular on the time to build between discovery and extraction—is in Mintz (2009).

[56] A proof is in the Appendix of Thakur et al. (2003).

Box 3. Marginal Effective Tax Rates on Resource Activities

Extending the framework of Box 1 above to allow for the use of capital K in production, generated by investment I that depreciates at a rate δ, and for exploration spending of e to generate (perhaps stochastically) discoveries of $D(e)$, the firm's value function becomes

$$V(S_t, K_t) = \max_{q,I,e_t}\left\{ p_t q_t - C(q_t, K_t, S_t) - e_t - I_t - T(q_t, e_t, \{I\}) + \frac{1}{1+r} E[V(S_t + D(e_t) - q_t), (1-\delta)K_t + I_t)] \right\}$$

where $T(.)$ describes tax payable, which depends on the details of the tax system (the term $\{I\}$ indicating that depreciation allowances generally depend on the past history of investment).

The firm's choice of extraction q, investment I and exploration e generates three necessary conditions; combining these with the impact of the resource and capital stocks on the valuation function, the corresponding METRs (the formalities are omitted here) summarize the wedge between the value of the marginal benefit from each of these decisions before and after tax:

- In the case of investment, the marginal benefit is the pre-tax rate of return on capital, which in equilibrium equals the net-of-depreciation user cost of capital. The METR is then the pre-tax rate of return on capital less the required after-tax rate of return on savings (conventionally expressed as an ad valorem rate by dividing by the pre-tax return on capital).

- For extraction, the notion of an METR is more complex (and rarely applied in practice) , since, as is evident from Box 1 and the later discussion of royalties, extraction this period is potentially affected by not only current taxes but al future taxes too. One approach would be to characterize tax impacts in terms of their effect on the equilibrium path of net current benefits from extraction. Recalling footnote 15, for example, if only a specific royalty a rate θ is in place, the METR would be $(1+r)\theta_t - \theta_{t+1}$: a positive METR then means that the royalty is increasing in present value, creating an incentive to bring extraction forward.

- The METR on exploration is the pre-tax marginal value of resource discoveries less the pre-tax cost, where the former will reflect taxes paid once production has begun. And the latter the tax treatment of exploration expenses.

The AETR and the METR on investment are related, as[56]

$$AETR = \tau + \zeta.METR$$

where τ is the rate of CIT and ζ the ratio of the net return on the marginal investment to the average pre-tax return.

The AETR and METRs are conceptually quite distinct, and can take quite different numerical values.[57] A rent tax of the type described above, for instance, has no impact on firms' decisions, so that each of the three METRs will be zero. The AETR, however, reflecting the revenue raised, will then be equal to the rate at which the rent tax is levied. And it is perfectly possible, for instance, for a tax system to be marked by negative METRs (reflecting the generosity of allowances) but a positive AETR (reflecting tax raised on infra-marginal profit).

The reason for an interest in METRs is clear: they indicate how the tax system is likely to affect key dimensions of project design. For the most part, however, the resource tax literature has focused more on AETRs than METRs. The reason for this merits some thought.

In non-resource contexts, the significance of the AETR is commonly seen as in affecting in which jurisdiction a company will choose to locate some footloose investment—a factory, say, or a distribution center. Countries will thus naturally be concerned that their AETR not be too far above those offered by their competitors. In the resource context, however, the underlying source of rents—the deposit itself—is not mobile across countries, and conventional theory would suggest that such rents can indeed be taxed at up to 100 percent without fear of driving investment abroad. Clearly it is important here to distinguish between the AETR calculated conditional on discovery (in which case it is quasi-rents that are being taxed, and as stressed earlier these cannot be taxed too heavily without discouraging exploration) or prior to exploration (in which case it is less obvious why 100 percent rent taxation should not be feasible). The basic point, remains, however, that the immobility of the underlying source of rents—potential resources in the ground—makes it less obvious than in non-resource contexts why countries should care how their tax take compares with that offered in other countries. Indeed one might expect their concern to be with ensuring that their tax take is *higher* than that available elsewhere, for reassurance that they extract at least as much rent as do others. In some cases, and not least in times of high resource prices, that does indeed seem to be their concern. In others, however, the concern appears on the contrary to be that the tax take not be too high relative to others, so that countries appear to be engaging in tax competition of the kind that has become familiar in non-resource contexts. Quite why such tax competition should occur in relation to what appear to be location-specific rents, however, is far from clear. This puzzle is taken up in Section IV below.

A final point. While distinct, the concepts of AETR and the METR on investment are formally related, with an important implication for the progressivity issue. The formalities are in Box 3, but the intuition is simple. Suppose that the METR is negative: this can quite

[57] It should be stressed too that the calculated AETRs and METRs rest on a host of assumptions—on how investments are financed, for instance, and (for the ATER) the assumed rate of return—and so should not be interpreted as having definitive precision.

plausibly be (and often is) the case for debt-financed investments in assets receiving accelerated depreciation, since then the cost of the investment is effectively deducted more than once. For a project that earns only a modest return, the AETR will be somewhat less than the statutory tax rate because of this marginal tax subsidy. For a project that earns an extremely high return, on the other hand, the AETR will be close to the statutory rate: if resource prices were infinitely high, to take an extreme example, the CIT base would be essentially revenue, which is also then essentially rent. The implication is that in such circumstances the AETR increases with the rate of return on the underlying project (so long as the METR is positive). Even without any progressivity built into the structure of the statutory rate schedule—the same rate applies to all levels of taxable profit—a standard CIT *is* then progressive in the sense that the term is commonly used in the resource literature.

IV. Challenges in Designing Resource tax regimes

The features of the resource sector set out in Section II—many of them applying also to other activities, but writ very large for resources—pose a range of challenges for tax design. This section considers how they might be addressed.

Discount rates and their implications

For such long-lived projects as are commonplace in the resource sector, the discount rates applied by government and investor—and differences between them—can play a critical role.

For investors, the discount rate applied to expected cash flows can be taken to be a (tax-adjusted) cost of capital reflecting the risks associated with the project and, importantly, the extent to which these are diversified across the company's entire range of activities (not, unlike national governments, simply those within any country): companies holding a portfolio of licenses are to some extent self-insured against the risks they face in terms of the extent, quality and accessibility of any single source. In principle too, companies' discount rates should reflect the opportunities for their ultimate shareholders to diversify risk within a wider portfolio of assets. On the other hand, their discount rates will reflect any political risk they perceive from the inability of the host government to commit to existing or announced tax and other policies.

The somewhat different considerations that arise for governments are examined in Box 4. These suggest, broadly speaking, that governments are likely to have relatively low discount rates when they attach a high weight to the well-being of future generations, enjoy relatively high income and fast prospective growth, are not strongly risk averse and are able to diversify away the risks associated with resource extraction. For many developing countries, especially those heavily dependent on the resource sector—even more so if there are just a few projects—some or all of these conditions are unlikely to hold, pointing to a relatively high discount rate. All this, moreover, relates to the discount rate that a fully benevolent government would apply. In practice, policy-makers also face political risk in terms of their own longevity in office. This in itself will likely cause them to discount future returns more heavily, implying the pursuit of policies that are inefficient from a wider social perspective.

Box 4. The Government's Discount Rate

Suppose that by for each unit of an asset costing P purchased today (period 1) the government can obtain an uncertain return of X tomorrow (period 2), and evaluates this decision in terms of maximizing expected utility

$$U(Y_1 - aP) + \frac{1}{1+\rho} E[U(Y_2 + aX)] \tag{4.1}$$

where a denotes the number of units of the risky asset bought, Y_t is (exogenous) income in period t (so that the argument of each function is consumption at the corresponding date) and ρ is the rate which future utility is discounted.

From the first order condition for the choice of a, the value placed on the asset is then approximately:

$$P \approx \frac{E[X]}{1+\rho + RRA(C_1)E[G] - \text{cov}[U'(C_2)X]} \tag{4.2}$$

where $\text{cov}(w,z) \equiv (E[wz] - E[w]E[z]) / E[w]E[z\}$ is a normalized covariance, $G \equiv (E[C_2] - C_1)/C_1$ is the expected growth in consumption, and $RRA(C) \equiv -U''(C)C/U'(C)$ is the coefficient of relative risk aversion (defined to be positive).[58] The certainty-equivalent discount rate used to value the asset thus has four components:

- The rate of pure time preference, ρ . This is essentially an ethical parameter, and the appropriate value has long been contentious. The Stern Review (2007) on climate change, for instance, follows a long tradition in setting this to zero on the grounds that it is improper to attach less weight to the well-being of future generations than to our own; others point that this is not how governments appear to behave, and is also ethically questionable: one alternative, for instance, is to maximize the well-being of the least well-off generation—which is likely to be the current one.
- The degree of curvature of the marginal utility function. This is as described by the coefficient of relative risk aversion, though (since this term also applies under perfect certainty) here it is capturing the extent to which the consumption of future generations is discounted because they enjoy higher consumption: the stronger the curvature, the more heavily future returns are discounted.
- The anticipated growth rate: faster growth implies less weight attached to future consumption, since that is associated (to an extent that depends on the curvature of marginal utility) with lower marginal utility of future consumption.
- The covariance between returns to the project and the marginal utility of consumption. This will be more negative—and the discount rate consequently higher—the more important returns to the project are to the aggregate economy (since then a low return is associated with low consumption and hence a high marginal utility). While there may be some opportunities for risk reduction through such devices as hedging, these operate only over periods that are quite short relative to project lifetimes. Attitudes to risk enter this final component too, with higher risk aversion, and hence a more sensitive marginal utility of income, again pointing to a higher discount rate.

[58] Rewriting the first order condition as $P = E[U'(C_2)X]/(1+\rho)U'(C_1)$, equation (4.2) follows on using the approximations $E[U'(C_2)] \approx U'(C_1)\big(1 - RRA(C_1).G\big)$ and $(1+\rho)/(1+\text{cov})(1 - RRA.G) \approx 1 + \rho - \text{cov} + RRA.G$.

The levels of the discount rates applied by government and investor can affect, for example, their rankings of alternative projects. Perhaps even more important for policy design, however, are differences between them. And here, for the reasons just given, the best working assumption is likely to be that in many lower income countries governments are likely to discount more heavily than many investors.

Differing discount rates matter, it should be stressed, even in the absence of uncertainty. Most fundamentally, they create scope for intertemporal trade between government and investor. If investors have a lower discount rate than the government, for instance, then by bringing forward their payments during the life of the project they can confer a benefit to the government—if unable to borrow against its future proceeds—that the latter will be willing to pay for by lowering future payments so much that the present value of returns to the investor, evaluated at its own discount rate, will rise. This in turn may affect optimal instrument choice. In the circumstances just described, for instance, both parties could gain—commitment problems aside—by levying an up-front fee (such as a signature bonus) rather than taxing ex post rents. Different discount rates may also rationalize deploying distorting tax instruments. They imply for instance[59] that the extraction path which maximizes the present value of rents for one party will typically not maximize it for the other. If the investor has a lower discount rate than the government, for instance, then it will tend to extract resources too slowly from the perspective of a government that attaches value to those rents (perhaps because it is taxing them). It will then wish to speed up extraction, which (recalling the discussion in Section III.A) it can do by setting a royalty that increases in present value over time.

Risk sharing

Alternative tax schemes imply different allocations between government and investor of the underlying risk associated with a project, creating scope for mutually beneficial trading of that risk between them. Both can gain by exploiting differences in attitude towards risk, with the party better able to bear more risk willing to do so in return for a higher expected return that the other is willing to pay.

To see what uncertainty might imply for optimal tax design, it is useful to abstract from the intertemporal dimension (for the moment) by supposing that project returns all accrue at a single future date and—also putting the time consistency issue aside—that the government can credibly commit to any state-contingent tax policy: that is, can announce, and will rightly be expected to implement, any schedule that prescribes some tax liability contingent on the outcome of the project (thought of, for simplicity, as simply the realization of an uncertain resource price). This tax schedule could take any shape: it might be progressive, with a

[59] Recalling (1.4) in Box 1.

higher average tax rate the more successful the project; or it could be regressive. Suppose too that the tax system itself is non-distorting, in the sense that it has no impact on the design of or payoffs to the project.

There is no uniquely optimal tax schedule in this setting, but some potential candidates will be inefficient in the sense that both parties could gain by instead adopting a different one. Box 5 characterizes the set of schedules that are Pareto-efficient in the sense of leaving no such room for mutual improvement.

Box 5. Progressivity and Risk-Sharing

Denote by $p(s)$ the return to the project in state s and by $\tau(s)$ the corresponding state contingent average tax rate. Pareto efficiency then requires that the government maximize its own expected utility subject to providing some given level of expected utility to the investors, the Lagrangean for this being

$$\sum_s \pi(s) U_G[p(s)\tau(s)] + \lambda \sum_s U_I[(1-\tau(s))p(s)], \qquad (5.1)$$

where $\pi(s)$ denotes the probability of state s occurring and the utility functions of government and investor are indicated by subscripts G and I. Taking the necessary conditions for this to define τ as a function of p, the optimal average tax rate can be shown to vary with profitability as[60]

$$\tau'(p) = (RRA_I - RRA_G)\Omega \qquad (5.2)$$

where RRA_j denotes the relative risk aversion of party $j = G, I$ and $\Omega \equiv -[(U_G''/U_G') + (U_I''/U_I')]p^2$ (>0) (all evaluated at the solution).

If, to take one extreme, the government is risk-neutral (so that $RRA_G = 0$), efficiency thus requires that $\tau' = 1$, so that all risk is borne by the government, and any payment to the investor is in the form of a fixed fee; and the opposite is true if it is the investor that is risk neutral. More generally, whether Pareto-efficient risk-sharing requires a progressive or regressive tax system thus depends on the relative risk aversion of the two parties. Assuming constant relative risk aversion, for definiteness, efficiency requires progressive rent taxation if and only if the government is less risk averse than the investor.

The conclusion is straightforward: efficiency requires that risk be borne more heavily by whichever party is less risk-averse.[61] If firms are risk-neutral, for instance, then efficient risk-

[60] The necessary conditions for the choice of the $\tau(s)$ imply that for all states s' and s

$$\frac{U_G'[p(s')\tau(s')]}{U_G'[p(s)\tau(s)]} = \frac{U_I'[(1-\tau(s'))p(s')]}{U_I'[(1-\tau(s))p(s)]},$$

the prime indicating differentiation. Taking this to define $\tau(s')$ as a function of $p(s')$, the result follows.

sharing requires that they receive all the uncertain return in exchange for payment of some fixed fee to the government. Pursuing that logic, efficient risk-sharing requires a progressive tax schedule if, and only if, the government has lower (relative) risk aversion than the investor. For the reasons above, the presumption must be that risk-sharing considerations argue against progressivity in many lower income countries.

The temporal dimension of uncertainty, reflected in the discussion of discounting above, can also have a critical impact on instrument choice. More risk-averse governments will have higher discount rates, all else equal, and so will prefer to get tax revenue sooner. This is best done, in principle, by intertemporal trade that does not dissipate the potential return to the project by tax-induced distortions: by auctioning, for example. If, however, credibility or other considerations prevent this being done, the (first-order) benefit from retiming tax revenue through the use of distorting instruments may offset the (second-order) loss that the induced inefficiency implies. Royalties, in particular, are commonly rationalized on these grounds: the government collects some revenue, including in the early days of the project, even if that project ultimately proves unsuccessful.

In this logic, the royalty functions akin to a minimum tax, which is a feature of the regular tax system in many countries (intended also as protection against transfer-pricing and other forms of profit-shifting). These minimum taxes are often specified as some fraction of turnover, and so are precisely analogous to an ad valorem royalty. This rationale suggests, however, that the royalty should be creditable against any profits-based tax (rather than, as is normally the case, deductible).

Responding to information asymmetries

Policy makers labor under the potential difficulty of being less well-informed on the geological and commercial circumstances of resource projects than are those to whom they entrust their implementation. One response is for governments to undertake the projects themselves, and indeed this remains commonplace in oil activities. The experience with state-run operations, however, has been less than entirely happy, as discussed in McPherson (2009), in part because asymmetries of information re-emerge to contaminate relations between national resource companies and other parts of government and wider society. Another possibility is the use of auctions, discussed briefly above and at more length in Cramton (2009)), a key purpose of which is precisely to elicit information from firms bidding for resource rights. Well-designed auctions that induce competitive bidding and information sharing can be relatively simple to administer, transparent and influence-resistant. At the

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[61] A full treatment of this issue is in Leland (1984), though focusing there on the marginal rate of tax (the higher this is, the more risk is borne by government) and on progressivity in the sense of an increasing marginal tax rate rather than, as here, an increasing average rate.

same time, if there are few potential bidders or if the terms and conditions attached to property rights are complex and negotiable, the government might be tempted to adopt more discretionary contractual approaches to assigning property rights. Alternatively, the government might wish to tailor the tax instruments at its disposal so as to limit the damage that lingering asymmetries information can do to the pursuit of its core policy objectives.

Suppose, for instance, that some projects are of two possible types, with either low or high costs for any given level of extraction. Firms know what type their project is. But the government—whose objective, assume, is simply to maximize its tax revenue—does not, and cannot rely on firms to self-report their profitability correctly. It can though observe (only) the level of extraction and the price at which the resource is sold: so it cannot implement a profit-based tax, but only a royalty (perhaps at a rate that varies with the level of output) and a fixed fee. Optimal policy, given that the government cannot tell directly whether the project has low or high costs, involves deploying both.

More precisely, it involves offering a choice between two tax packages: one with no royalty but a relatively high fee, the other a royalty but a relatively low fee. The reasoning behind this is spelt out in Box 6, but the essential intuition is straightforward. At any given royalty rate, extraction will be greater for the low than for the high cost project: firms are thus more anxious to avoid paying them when costs are low, and to do so will be willing to pay a larger fixed fee. While the royalty distorts the extraction level for the high cost project, the inefficiency this creates is more than offset by the ability to discourage low cost projects from masquerading as high cost ones, and hence to extract greater rent from them without jeopardizing the revenue from high cost projects.

Box 6. Optimal Tax Design With Asymmetric Information—More intuition

Suppose that the government starts by deploying only a single fixed fee *F*. To maximize revenue, it will set this as high as is possible without making the high cost project unprofitable. Note that extraction will then be greater if the project is low cost than if it is high: $q^1 > q^2$, say.

Now suppose the government offers firms a choice: they can either produce output q^1 and continue to pay the fixed fee, or they can produce the lesser amount q^2 and pay a small royalty $d\theta > 0$ together with a fee slightly reduced by $dF < 0$, where these have been calibrated to have no effect on the after-tax profit of a high cost project initially producing q^2: that is, $q^2 d\theta + dF = 0$. The change in the tax paid by this high cost project is then $q^2 d\theta + \theta dq^2 + dF = 0$, and so, since there is initially no royalty, is also zero. A firms with a low cost project now has a choice: it can remain at q^1 as before, or it can choose the royalty regime. Denoting the optimal level of output in that latter case by $\hat{q}^1$, it will in the latter case pay tax of $\hat{q}^1 d\theta + F + dF$. Comparing this with its initial tax payment of *F*, the implied a change in tax payments is $d\theta(\hat{q}^1 - q^2)$; which, since the low cost project will produce more than the high at any royalty rate, is strictly positive. Adding to this the reduction in pre-tax profits implied by the distortion of its output level if this option is chosen, the low cost project strictly prefers the option of producing q^1 and paying no fee. But the government can exploit that strict preference by requiring that a slightly higher fee be paid if q^1 is produced. By offering these different $\{\theta, F\}$ packages, the government can thus increase its revenue.

The process cannot continue indefinitely, since when the initial royalty is strictly positive a perturbation of this kind that leaves after-tax profits of the high tax project unchanged will reduce tax revenue (as a consequence of the reduction in output). Nor can it be optimal to impose a royalty on the low cost project: if a positive royalty were set, slightly lowering it would increase pre-tax profit, and this could be extracted by setting a somewhat higher differential fee, without making it attractive for the low cost project to masquerade as high cost.

One other feature of the optimal tax package should be noted: it leaves the low cost project earning strictly positive rents. This is because any tax package that is intended to ensure that high cost producers break even must imply that low cost producers earn strictly positive profit, since they can always pretend to be high cost and (actually being more efficient than high cost producers) earn strictly positive rents by doing so. In the presence of asymmetric information, firms may enjoy informational rents that cannot efficiently be taxed away.

The tax design problem becomes still more complicated if production extends over several periods. Under the scheme just described, for instance, firms effectively reveal whether the project is high or low cost by the tax package they choose. If tax rules could be reset thereafter—and (as is plausible) costs were correlated, so that a project that had low costs in one period will also have low costs in the next—then low cost projects would have an incentive not to reveal themselves as such in order to avoid heavier taxation in the future. Osmundsen (1998) shows that in this case optimal policy, assuming (perhaps heroically, given the time consistency problem) that the government is fully able to commit, again requires offering a menu of royalties and fixed charges but with the former now depending not only on current output but also on output in previous periods.[62]

The solutions to the optimal tax design problem in these (relatively simple) cases are evidently complex: even in the one-shot problem, for instance, the royalty is nonlinear in output. They do stress, however, the potential value of deploying royalties as part of the response to problems of asymmetric information: while distorting extraction decisions they can provide an indirect way of ensuring that more profitable projects pay more tax. This remains so even when the government cannot implement a nonlinear royalty, but must apply the same rate at all output levels (and so must also offer only a single license fee). It can be shown that it will indeed then be optimal to set a positive royalty rate: this means setting a lower fee than would otherwise be the case in order for the high cost project to go ahead, but the consequent revenue loss is more than offset by the revenue gained from applying the royalty to the high level of output that will remain optimal for the low cost project.

The potential usefulness of royalties is amplified the greater are the difficulties of accurately measuring costs, as, not least, when firms are adept at shifting taxable income to lower-tax jurisdictions. Indeed recognition that revenues may be easier for the tax authorities to monitor than costs suggests that royalties might be combined with rent taxes to exploit the advantages of both. To the extent that firms can overstate their costs for profit tax purposes, they will have an incentive to undertake excessive expenditures. This can be countered by a royalty that applies only on revenues. Box 7 presents a stylized example to illustrate the point, showing how a royalty can correct the inefficiency associated with overstatement of costs for tax purposes and lead to efficient rent extraction. In that simple example, a royalty can be used to tax away revenue in the same proportion as the firm understates costs, leaving an undistorted measure of rents as the base for the rent tax proper.

[62] Osmundsen (2009) discusses these results further.

Box 7. Royalties and Rent Taxes to Alleviate Asymmetric Information

Suppose a resource firm incurs a cost of I in the first period to generate a quantity of resource $q(I)$ with certainty in the second period, where $q' > 0 > q''$. The resource sells for a price p and costs $c(q(I))$ to extract. The government imposes an ad valorem royalty at the rate θ on revenues and a tax on reported rents at the rate τ. Revenues can be perfectly observed by the government, whereas firms can over-report costs with limited chances of being caught. Suppose that the firm reports costs that are simply some multiple $\lambda(\tau) \geq 1$ of its true costs, with $\lambda', \lambda'' \geq 0$ (the higher the tax rate, the greater the incentive to overstate costs); the same overstatement applies to both initial costs and extraction costs.

The firm chooses I to maximize the present value of its after-tax rents:

$$\pi = -I(1-\tau\lambda(t)) + \frac{(1-\theta-\tau)pq(I) - (1-\tau\lambda(\tau))C(q(I))}{1+r}, \qquad (7.1)$$

the first-order condition for which can be written

$$((1-\theta-\tau)p - (1-\tau\lambda)C')q' = (1-\tau\lambda)(1+r). \qquad (7.2)$$

From this, investment $I(\theta, \tau)$ can be shown to be decreasing in the royalty rate θ and (at zero royalty and for $\lambda > 1$) increasing in the rent tax rate: the royalty evidently discourages production, whereas the over-statement of costs means that the rent tax effectively acts as marginal subsidy to investment.

Indeed in this simple example the inefficiency can be eliminated entirely, by setting the two instruments so that $\theta = (\lambda - 1)\tau$. After-tax rents in (7.1) then become

$$\pi = (1-\tau\lambda)\left(-I + \frac{pq - C}{1+r}\right) \qquad (7.3)$$

so that the system becomes equivalent to a tax on rents at the rate $\tau\lambda$.By combining royalties and a rent tax set at appropriate levels, the government can then effectively choose the proportion of rents to extract from the firm.

But the merits of royalties as a response to informational problems should not be overstated. They are not without their own implementation difficulties (as discussed in Calder (2009a) and Otto et al (2006)). Conversely, the difficulty of observing business costs is a pervasive problem that does not preclude governments operating business income taxes more generally. And explicit rent taxes may in some respects be even simpler to implement (as discussed in Calder (2009) and Land (2009)): they do not require the accurate measurement of depreciation, for instance. Thus countries with relatively strong administrations, such as Norway and the UK, have felt able to dispense with royalties in their oil tax regimes. Even where administration is weak, royalties are best seen as an adjunct to, not a substitute for, effective profit tax regimes.

Dealing with time consistency

A government's inability to commit to its future tax treatment of resource projects can hurt both itself and investors. In principle, it ultimately restricts attention to tax policies that are 'time consistent,' in the sense that the government will find them optimal to implement ex post given that investors' behavior is predicated on it indeed behaving in such ways (so that investors are not surprised, and the government always acts in its own best interests). The problem this creates is that such policies are generally inferior, for all concerned, to those that could be achieved if the government could commit. Suppose, for example, that the government is unlimited in its revenue needs and so, ex post, will want to extract all the return from any successful project. The only time consistent equilibrium then has no private investment: investors rightly expect that their quasi-rents would be expropriated if the project succeeds, and so do not invest. Both sides would be better off if the government could credibly promise to tax away only part of the returns from the project.

Less extreme views of the government's preferences lead to less extreme outcomes. If the government values not only tax revenue but also (and strongly enough) after-tax profits accruing to the investor, then—an example of this will be discussed further below—it will typically not expropriate all quasi-rents once investment had been sunk. Some investment may thus continue to be made, but at a reduced level. The basic difficulty thus remains: investment will be too low relative to the fully efficient outcome that would be obtained if the government could commit.

There may be circumstances—as with the very high oil and mineral prices of mid 2008, perhaps—in which outcomes are so extraordinary, relative to what might have been conceived when tax arrangements were entered into, that some renegotiation is seen even by investors as generally reasonable. And countries with a strong reputation for good governance may be able to change tax rules frequently without very marked damage to investors' confidence: the UK, for instance, has altered the taxation of North Sea oil activities very frequently, without disturbing investors too dramatically. Nevertheless, the potential benefits of achieving credibility in resource taxation are substantial. A key question is thus how governments might do so, or at least, what kind of tax design time consistency may require of them. There are a number of possibilities.

One is to provide an up-front cash subsidy to investments, or equivalently make negative tax liabilities arising from initial investment cash expenditures fully refundable[63] (as Norway now does for exploration spending for instance). This may be appropriate where countries

[63] Doyle and van Wijnbergen (1984) show how tax holidays and subsidies can result from a sequential bargaining framework between a host government and multinational in the absence of commitment. Vigneault (1996) finds that time-consistent tax rates can increase over time.

have strong fiscal positions and low discount rates relative to potential investors—as perhaps in Norway—or, at the opposite extreme, for countries with such poor reputation and modest prospects that investment is otherwise completely blocked. But the disadvantages are evident: most countries are looking to obtain revenue in the early days of a project, not to give it away.

A second possibility, when interactions with investors are repeated over time—perhaps reflecting knowledge of rich deposit possibilities and a consequent expectation of a continued flow of developments (as in the Norwegian case, as stressed by Osmundsen (2009))—is for the government to seek to acquire a reputation for keeping its word. This can be supported by investors adopting a punishment strategy: refusing to invest at all for several years, for example, once commitments have been violated. In such circumstances, if the government has a sufficiently low discount rate it may prefer to honor its word rather than take the short-term benefit of setting a higher tax than promised. But circumstances may not always be favorable to such an outcome. The necessary coordination and commitment amongst investors may be lacking, and governments can turn over quickly. For post-conflict countries, not least, establishing a good reputation, and providing assurance to investors that conflict will not re-erupt, is likely to take some time. And some countries have only limited likely reserves—in some cases just one major development, in others reserves that are expected to be exhausted relatively soon—so that the risk of deterring future investments may have little force.

Governments can also seek to provide some form of legal assurance on future tax policy: a government cannot bind its successors, but it can try to restrict their room for manouver. Guarantees might be provided in the constitution, though in some countries constitutional amendments are fairly commonplace, and as Osmundsen (2009) notes the time required to change constitutions may be modest relative to project lifetimes. International investment agreements, with the force of treaty, commonly provide for at least reasonable compensation in the event of expropriation.[64] Violating these may be especially costly, given the wider signal that would send, but the protection is only against the most extreme outcomes. More targeted, and quite common, is the inclusion of fiscal stability clauses in sectoral laws or specific agreements. A range of issues that arise in designing their precise terms—whether for instance a premium should be charged in return for such stability assurances—are discussed in Daniel and Sunley (2008). They also stress, however, that politics can nevertheless exert significant pressures for the effective abrogation of such agreements; if not explicitly, then through significant encouragement of private companies to renegotiate the terms of their agreements 'voluntarily.'

[64] Chapter 11 of the North American Free Trade Agreement being an example, where expropriation is defined to include taking "a measure tantamount to nationalization or expropriation of an investment."

It may also be that some features of tax design can be exploited to ease the difficulties created by the inability to commit. Is it the case, in particular, that schemes with some degree of progressivity—the average tax being higher at higher rates of ex post return—are helpful in this context, in the sense that both investors and government can fare better than they would if progressivity were precluded?

It may be that time consistent tax schemes are indeed progressive. Appendix 2 gives an example of this, in which a government attaches some constant marginal value to tax revenue and a positive but decreasing marginal value to realized after-tax profits. In this case, it will indeed impose a progressive tax on quasi-rents: it leaves them entirely untaxed if low enough (profits then having more value than tax revenue) but at an increasing rate above that (leaving investors with the level of after-tax profits that has the same marginal value as tax revenue). This result is certainly special—time consistency would require a regressive schedule, for instance, if the value attached to profits were constant and that to tax revenue decreasing—but suggestive nonetheless.

Intuition suggests, moreover, that progressive rate schedules may have particular appeal in terms of political economy, being more robust against political pressures in the event of high return outcomes than are proportional schemes. This indeed has become part of folk wisdom—at least for some folk—in this area.[65] Box 8 sets out a simple political economy model in which this indeed turns out to be the case, so long as domestic electors are sufficiently risk-averse. This latter feature contrasts interestingly with the earlier arguments on dealing with uncertainty itself. The conclusion there was that if, as is in many cases plausible, host governments are relatively risk averse, progressive taxation is unappealing. The political economy of time consistency, however, suggests the exact opposite: it is where risk aversion is high that progressivity is desirable. The model is highly stylized, but makes the point that the strongest case for progressive resource tax arrangements in lower income countries may well be in dealing with the politics of time consistency, and that determining the optimal degree of progressivity is likely to involve trading this off against the associated costs of risk-bearing.

[65] Nellor and Robinson (1984) provide an early account of the time consistency issue in resource taxation that pays explicit attention to political economy aspects. Assuming that investors perceive some arbitrary link between ex post profitability and the likelihood of their being expropriated, they conclude that there will be some relationship between realized cash flows and the average tax paid, but derive no sharp conclusions on its nature.

Box 8. Politics and Progressivity in Resource Taxation

Suppose an incumbent government knows it will face re-election after the state-contingent return to some project¸ $p(s)$, has become known and—free to set whatever tax rate it then chooses—it has taxed these at rate $\tau(s)$ and distributed the proceeds equally across all voters, yielding each welfare of $U[\tau(s)p(s)]$ (the number of electors being normalized at unity). Its opponent will be a 'populist' party that will instead tax away all and share out all returns, so yielding each voter $U[p(s)]$. Voters do not necessarily vote for the party offering the higher payout, however, since they also have ideological preferences between the two, described by a parameter ϕ distributed across the voter population, independent of the state realized and having (without loss of generality) mean zero. Thus voter *j* will vote for the populist party in state *s* if and only if

$$U(p) \geq U(\tau p) + \phi_j \,. \tag{8.1}$$

The incumbent party wishes to remain in office, reflecting some non-monetary 'ego-rents' from which it derives value. Suppose too, however, that if it diverges from its pre-announced tax policy it will suffer some form of punishment, perhaps in the form of reduced future investment.

The incumbent can achieve both these objectives—be reelected and keep its promises—if it announces a state-contingent tax schedule such that, for every *s*, the median voter supports its re-election. This requires the schedule to be such that, for all *s*,

$$U(p(s)) = U(\tau(p(s))p(s)) + \phi_{median} \ , \tag{8.2}$$

which is consistent with setting a tax rate of less than 100 percent so long as the median voter has an ideological preference for the incumbent. More precisely, it is shown in Appendix 3 to require that $\tau'(p(s))$ be strictly positive at all *s*—meaning a progressive schedule—if and only if $RRA(\tau(p(s))p(s)) > 1$, so that the voters' relative risk aversion at all outcomes is greater than unity.

One other point is worth noting. This is that the weakness of tax administration in many countries may in itself mitigate the time consistency problem: if host authorities are simply not capable of levying heavy taxes on ex post rents—perhaps because they have very little ability to monitor profit-shifting arrangements—then investors have little to fear. In some contexts, it may for this reason even be optimal for governments to deliberately under-develop their administrative capacity: in effect, a weak administration can itself serve as a commitment device (Boadway and Keen (1998)). The point should not be over-stated, given the extreme weakness of tax administrations in many lower income countries (and, in any event, threats of non-renewal of licenses and the like can be effective even without a strong tax administration). Nevertheless, the reality is that weakness of tax administration serves to some degree as a commitment device.

International tax competition and coordination

As noted earlier, it is easy to explain why a country seeking to attract a new car factory might want to offer an AETR that is not too far above those available elsewhere, or, similarly, why it may not wish its statutory rate of CIT to be far above those elsewhere, given the opportunities for profit-shifting this can create. With countries shaping their tax policies in this way, the international corporate tax competition that now appears under way—reflected by a substantial fall in both statutory rates and AETRs—comes as no surprise. But it is far from obvious why a country considering a new resource development should have the same concern with the AETR: the car factory could be located elsewhere, but the resource deposit cannot. Resolving this puzzle—why countries might be concerned at having a higher resource AETR than elsewhere—is more than an intellectual curiosity: it may affect, for example, the case for international coordination in resource taxation.

This question has received little attention. Part of the answer, no doubt, is that similar transfer pricing issues arise as in other sectors, not only with the standard CIT but also in relation to such sector-specific taxes as royalties. Difficulties can also arise with smuggling if, for example, export tax rates differ across countries or—a case in which the resource itself is effectively mobile—when border-crossing deposits can be exploited from more than one jurisdiction. But the concern seems to be deeper than that.

One possibility is that production is limited by the scarcity of some input other than the resource itself, which countries must therefore compete to attract. Osmundsen (2005)—perhaps the only paper to address this issue—suggests that this might be managerial or technical capacity. Or the constraint might be in the finance available to resource firms. In so far as the shadow value of such constraints are not properly accounted for as a cost in AETR calculations, governments would need to offer packages that leave an after-tax return adequate to attract these factors. A difficulty with this line of explanation, however, is that—at least if entry is not blocked—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.

Other explanations might focus on imperfections of competition, not only in terms of entry barriers limiting the supply of scarce inputs but also in restricting output supply so as to raise the world price of the resource at issue. A company that is large in the world market for some resource, for instance, might choose not to develop now all available deposits, even if that would be profitable at the current price, because it recognizes that doing so would cause the price to fall: it might choose to open only one of two possible gold mines, for instance, with the two host governments then having an incentive to offer the more attractive tax terms. But the practical importance of such considerations—and again, new entry should ultimately constrain such behavior—is unclear.

A third possibility is related to the time consistency issue: in seeking to acquire a reputation conducive to potential investors, countries may seek to benchmark their own systems relative to those available elsewhere. It may be, for instance, that credibility is enhanced by offering to new projects terms comparable to those that have proved acceptable to governments and investors alike elsewhere.

If countries do indeed compete in the resource tax regimes they offer, it could be that by doing so they ultimately derive no benefit but, to the contrary, simply cause each other mutual damage. If, for instance, they compete to attract some factor, such as managerial capacity, that is scarce in the aggregate but mobile between them, it could be that tax rates end up inefficiently low: acting collectively, countries could raise revenue relatively efficiently from a relatively inelastic base, but by to failing to coordinate their policies they dissipate this opportunity, and so must resort to less efficient tax instruments or forego worthwhile spending. A case can then be made for international or regional coordination to limit such tax competition, and there has been some interest in this in the resource context: WAEMU, for example, has adopted a mining code[66] that in specifying some tax benefits – including a three year tax holiday from the start of production—may serve to limit members ability to compete by offering still stronger tax incentives. There has been discussion too of adopting common limits on tax benefits (including an avoidance of tax holidays) in South Africa Development Community.[67] There is a large literature focused on the desirability or otherwise of such agreements intended to limit downward tax competition: on whether such coordination remains desirable, for instance, when policy makers may spend some part of tax revenues unwisely or corruptly, on whether coordination by a subset of countries can worsen their position by exposing them to more aggressive competition from third countries, and on the implications of alternative forms of coordination. Many of these generic considerations[68] are as relevant to the resource sector as to any other.

But there are differences. One is that since the reasons for any tax competition are less fully understood, so too the case for coordination is less clear: if downward pressure on tax rates reflects imperfections in market competition, for example, coordination is likely to be inferior to reducing those imperfections. Another potential concern is the time consistency issue raised above. Indeed in this respect the stronger case could perhaps be made for coordination intended to impose common *maximum* rates—achieving commitment by international agreement—not minima.

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[66] Reglement 18/2003/CM/UEMOA.

[67] United Nations Economic Commission for Africa (2004).

[68] Reviewed for example by Wilson (1999) and Keen (2008).

The usual arguments for international coordination of business tax policies have as yet had relatively little impact on practical policy. It is important to recognize, however, that they do not evidently apply with equal force, or in the same way, in relation to resources.

V. CONCLUDING REMARKS

It is conventional to stress that no single resource tax regime will suit all countries and circumstances. That is undoubtedly so. Low income countries may reasonably be supposed to discount the future more heavily than others, for instance, and so to be more impatient to receive revenues relatively early in projects' lifetimes. They may also be less willing to bear risk than the large multinationals with which they deal, and be more constrained in terms of administrative capacity. These considerations may point to heavier reliance on royalties than elsewhere. Geology also matters: a country with a single large deposit may face greater time consistency problems than those with strong prospects of continued discovery. While country characteristics must thus shape practical policy advice, theory does provide some fairly specific guidance.

One lesson is that it will typically not be optimal to rely on a single tax instrument, whether auction, royalty, rent tax, or other. This is less because of multiple objectives—we have seen for instance that it may be optimal to use both royalties and fixed fees when the aim is simply to maximize revenues—than because of the range of challenges that governments face in crafting their resource tax regimes: shaping the preferred time path of revenues, dealing with problems of time consistency and asymmetric information, fitting the regime to their administrative capacity, and responding to political economy pressures. The discussion above points to a range of considerations that should inform the design of resource tax regimes to address these challenges. Amongst these:

- There is no easy solution to the fundamental time consistency problem, but building in some marked degree of sensitivity of tax payments to underlying profitability may help ease political economy pressures to renege on initial agreements. This might ideally take the form of an explicit rent tax, so as to minimize consequent distortions, though there may be a case for sensitivity to short-term prices rather than long-run rents since political pressures may arise at times of high resource prices even if rents remain moderate.

- Auctions—widely used in oil and gas operations, though not (yet) for minerals—have considerable potential appeal as a response (arguably the best response) to problems of asymmetric information, and (when the government's discount rate is relatively low) as a way of ensuring that substantial revenue is received early in the project lifetime. Their effectiveness may be less, however, where time consistency is perceived as a significant problem: participants will then bid less than they otherwise would in the expectation of an additional subsequent burden if the project proves highly successful. One way to mitigate this may be by combining the auction with a non-distorting rent tax: while the latter will reduce the amounts bid, to the extent that it eases the time consistency problem it will also reduce the discount for sovereign risk.

- Much emphasis is often placed on the potential for royalties to distort producers' decisions on exploration and development, the pace of resource extraction and the closure of operations. There are circumstances, however, in which some such distortion of private decisions actually enhances social efficiency. One is that in which operators do not have proper incentives to leave resources in the ground at the end of their contract period: in this case, a royalty that increases as the terminal date of the contract approaches can in principle serve a useful corrective role (though it seems they are rarely used in this way in practice). Perhaps more fundamentally, royalties may also have a distinct role to play in responding to informational asymmetries: they can be used to counteract the tendency towards the overstatement of costs under a rent tax, and—though the point appears as yet to have had little impact on practice—can be combined with other instruments, such as a fixed fee, to enable liability to be differentiated across project and firm type in a way that raises more revenue than could either instrument on its own. What does seem clear is that while royalties will often have a proper role in resource regime, sole reliance on them risks creating costly distortions.

- While the resource literature has focused on the particular resource rent tax (RRT) of Garnaut and Clunies Ross (1975, 1979, 1983), there are many other forms of tax (indeed, infinitely many) that—in the absence of informational asymmetries, and with proper carry forward arrangements (including in relation to exploration expenses, especially on unsuccessful projects)—are non-distorting. A potential weakness of the RRT within this class of taxes, and one that seems to be keenly felt in practice, is that revenue accrues to the government only relatively (perhaps very) late in the project's life, once cumulated rents are positive. There are other rent taxes, equivalent to the RRT in present value, that yield revenue earlier (by not giving immediate relief for all cash outlays). One such, for instance, is the Allowance for Corporate Equity (ACE), under which all financing costs (including a notional return on equity) are deducted, along with depreciation (calculated at an essentially arbitrary rate). The ACE and other such schemes have attracted increased attention in recent years as potentially desirable reforms of the general corporate income tax. They may have particular appeal for resource activities too.

Appendix 1. Optimality of the RRT Among Cash Flow-Based Rent Taxes

Continuing the notation of Box 2, taking B_t as given, consider the effects of a small change in σ_t combined with such a change in σ_{t+1} as to leave B_{t+2} unchanged. Noting that *B* evolves as

$$B_{t+1} = R_t - C_t + (1 - \sigma_t + r)B_t \quad , \tag{A1.1}$$

this implies that

$$dB_{t+1} = -B_t d\sigma_t \tag{A1.2}$$

$$dB_{t+2} = 0 = -B_{t+1} d\sigma_{t+1} + (1 - \sigma_{t+1} + r)dB_{t+1} \quad . \tag{A1.3}$$

The present value of government revenue evaluated at the discount rate ψ (which may differ from *r*) is proportional (the tax rate is taken as given) to $\sum_s \sigma_s B_s (1+\psi)^{-s}$. The revenue effect of the perturbation is thus (after post-multiplying by $(1+\psi)^{t+1}$) proportional to:

$$B_t d\sigma_t (1+\psi) + B_{t+1} d\sigma_{t+1} + \sigma_{t+1} dB_{t+1} \tag{A1.4}$$

$$= B_t d\sigma_t (1+\psi) + (1 - \sigma_{t+1} + r)dB_{t+1} + \sigma_{t+1} dB_{t+1} \tag{A1.5}$$

$$= (\psi - r)B_t d\sigma_t \tag{A1.6}$$

where (A1.5) substitutes for $B_{t+1} d\sigma_{t+1}$ from (A1.3), and (A1.6) for dB_{t+1} from (A1.3). From (A1.6), if $\psi > r$ then it is optimal to raise (lower) σ_t whenever B_t is positive (negative). Supposing that σ_t must lie between zero and one, the result follows.

Appendix 2. Time Consistency With Less Than Full Ex Post Taxation—An Example

Suppose that an investment of K yields a return of $sp(K)$ in state s, which occurs with probability $f(s)$, with s non-negative in all states (since projects can be shut down if they fail to cover variable costs), and $p(K)$ strictly increasing and strictly concave in K. The efficient level of investment (assuming risk neutrality) is then that which maximizes $W(K) \equiv \int_0^\infty sp(K)f(s) - K$, the necessary condition for this being

$$W'(K) = p'(K)\int_0^\infty sf(s) - 1 = 0, \qquad \text{(A2.1)}$$

which simply says that investment is chosen such that its expected marginal product equals its marginal cost (unity). Suppose now that the government announces the tax rate $\tau(s)$ once the investment decision has been made and the state of nature revealed, and does so to maximize the sum of tax revenue and some strictly concave function υ of after-tax profit:

$$\tau sp(K) + \upsilon[(1-\tau)sp(K) - K]. \qquad \text{(A2.2)}$$

Suppose that the government cannot make negative tax payments, and define γ to be the level of profit at which it is just indifferent, at the margin, between tax revenue and private profit: that is, $\upsilon'(\gamma) = 1$. It is then straightforward to see that it will set a tax rate of zero if pre-tax profits $sp(K) - K$ are less than γ, and for higher levels of profit will set τ so that after-tax profits are exactly γ. This latter implies that

$$\tau(s,K) = 1 - \left(\frac{\gamma + K}{sp(K)}\right), \qquad \text{(A2.3)}$$

which is increasing in ps. The tax schedule is thus progressive: the tax rate is zero below some level of pre-tax profit, above which it is charged at an increasing average and marginal rate.

Anticipating such ex post taxation, the firm chooses K to maximize its net profit

$$\int_0^{\eta(K)} \{sp(K) - K\} f(s)ds + (1 - F(\eta(K))\gamma \qquad \text{(A2.4)}$$

where $\eta(K)$, implicitly defined by

$$\eta(K)p(K) - K = \gamma \qquad \text{(A2.5)}$$

is the level of the shock at which tax becomes payable, and $F(s)$ is the cumulative distribution function of s. The firm's necessary condition is thus

$$\int_0^{\eta(K)} \{sp'(K) - 1\} f(s) ds = 0 \tag{A2.6}$$

(the terms through the integrand in the first term of (A2.4) and the second term canceling by (A2.5)). Note that since p is strictly increasing, this implies that

$$\eta(K) p'(K) - 1 > 0 \tag{A2.7}$$

so long as $F(\eta) > 0$. At the level of investment defined by (A2.6), (A2.1) implies that

$$\begin{aligned} W'(K) &= \int_{\eta(K)}^{\infty} \{sp'(K) - 1\} f(s) ds \\ &\geq \{\eta(K) p'(K) - 1\} \{1 - F(\eta(K))\} \end{aligned}$$

which, from (A2.7), is strictly positive if there is some possibility that the government would impose a tax if the efficient level of investment is undertaken (so that $F(\eta) < 1$), there will thus be under-investment in the sense that $W'(K) > 0$.

This example is special. If, for instance, the government attaches constant weight to after-tax profits but decreasing weight to tax revenue, then the time consistent tax scheme is regressive: it fully taxes quasi-rents below some critical level, above which it applies a decreasing tax rate. Investment, however, would again be inefficiently low.

Appendix 3. Conditions for a progressive rent tax in political equilibrium

Differentiating (8.2) with respect to p gives:

$$U'(p) = U'(\tau p)\{\tau + p\tau') \tag{A3.1}$$

so that $\tau'(p) = F(\tau)/\,pU'(\tau p)$, where $F(\tau) \equiv U'(p) - \tau U'(\tau p)$. Since $F(1) = 0$, to establish that $\tau'(p) > 0$ it thus suffices to show that $F'(\tau) < 0$. Differentiating gives

$$F'(\tau) = -U'(\tau p) - \tau p U''(\tau p) \quad = \quad -U'\left(1 + \frac{\tau p U''}{U'}\right) \quad = \quad -U'(1-R), \tag{A3.2}$$

and the result follows.

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