mineral resource taxation in australia

an economic assessment of policy options

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foreword

Exports of mineral resources from Australia were valued at $92 billion in 2005-06, accounting for 47 per cent of total exports of goods and services. Australia has, and is likely to continue to have, a significant international competitive advantage in the export of many mineral resources owing to the size and quality of domestic economic demonstrated resources. For example, at the end of 2004, Australia was ranked in the top two countries for economic demonstrated resources of gold, copper, lead, zinc, nickel, mineral sands, bauxite and uranium.

The Australian, state and territory governments currently apply a range of profit based royalties and output based royalties to petroleum and minerals industries in their respective jurisdictions. The aim in resource taxation policy is to enable governments to collect a reasonable return from the extraction of the community's mineral resources, while ensuring that industry outcomes remain efficient and administrative costs are not excessive.

In this study, an economic assessment of resource taxation policy options in Australia's mining sector is provided. A major focus in this study is to assess the potential net economic benefits of extending a profit based royalty such as the Australian Government's petroleum resource rent tax system to onshore mineral resources. A complex system of mainly output based royalty arrangements currently applies to onshore mineral resources under the jurisdiction of state and territory governments.

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January 2007

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study objectives and approach

- By international standards, Australia has substantial natural wealth in the form of mineral resources. In 2005-06, Australia's mineral resources exports were valued at $92 billion, accounting for 76 per cent of total commodity exports, 60 per cent of total merchandise exports and 47 per cent of total exports of goods and services (see table 6 in ABARE 2006a).
- The objectives in this study are to provide an economic assessment of resource taxation policy options in Australia's mining sector and, in particular, to assess the potential net economic benefits of extending a profit based royalty such as the Australian Government's petroleum resource rent tax system to onshore mineral resources. A complex system of mainly output based royalty arrangements currently applies to onshore mineral resources under the jurisdiction of state and territory governments. Current resource taxation policies in Australia are summarised in chapter 2 of this report.
- In Australia, mineral resources are assumed to be owned by the community. Governments, on behalf of the community, assign exploration and production rights to the private sector in return for a resource royalty payment. The objective in resource taxation policy is to enable the government to collect a reasonable return from the extraction of the community's mineral resources while ensuring that the costs of the policy are not excessive. These costs include the administrative costs to the government and industry as well as any negative distortions to private investment and production decisions (the efficiency implications of the policy). In general terms, a resource taxation policy option is preferred if the same resource royalty payments are collected at lower cost than under an alternative resource taxation policy option.
- The economic implications of a range of profit based royalties and output based royalties are examined in this study (chapter 3). Some of the major economic impacts are illustrated by applying key resource taxation policy options to several hypothetical resource development projects (chapter 4). Some key features of the economic analysis and project simulations are summarised and the implications for resource taxation policy in Australia are discussed (chapter 5).

resource rent and policy options

- The economic justification for resource taxation policy is the presence of resource rent or a return to the mineral resource. Resource rent is the super-normal or excess profit that would be earned in the exploration, development and extraction of mineral resource deposits (ore deposits and fossil fuel fields). That is, resource rent is the profit after private investors have received a normal rate of return on their exploration and capital expenditures, including an appropriate risk allowance. Resource rent exists, for example, through the quality differential of resource projects – profitability increases with the quality of the mineral resource deposit, everything else remaining constant.
- The resource taxation policy options examined in this study include several profit based royalties and output based royalties.
- *Profit based royalties* are levied on the net cash flow or profit of a resource project:
  - The ***Brown tax*** is a profit based royalty that provides a useful benchmark against which other policy options may be assessed – under the Brown tax, the government collects a constant percentage of a project's net cash flow in years in which profits are earned and provides cash rebates to private investors in years of negative net cash flow.
  - The ***resource rent tax*** is a profit based royalty that provides governments with an approximation to the Brown tax but avoids cash rebates in years in which losses are incurred – under a resource rent tax, the government collects a constant percentage of a project's net cash flow where losses (negative net cash flow) are accumulated at a threshold rate and offset against future profit.
- *Output based royalties* are levied on the volume or value of production of a resource project:
  - The ***ad valorem royalty*** is an output based royalty whereby the government collects a constant percentage of the value of production.
  - The ***specific royalty*** is an output based royalty whereby the government collects a constant (dollar) amount per physical unit of production.
- The petroleum resource rent tax applies to offshore areas under the jurisdiction of the Australian Government, excluding the North West Shelf (NWS) permit area and the Joint Petroleum Development Area (JPDA). The petroleum resource rent tax is levied at a rate of 40 per cent; general project expen-

ditures are accumulated at the long term government bond rate plus 5 per cent; exploration expenditure is transferable between projects within the same company and is immediately deductible; and a 150 per cent tax deduction applies to exploration expenditure in designated high risk frontier areas (announced in the 2004-05 budget and to apply for a five year period). Different threshold rates apply to exploration expenditure by new companies.

- Ad valorem royalties generally apply to onshore oil and gas extraction, coal mining and metal ore mining, although royalty rates typically differ between jurisdictions and some arrangements have been altered in an attempt to more closely proxy a profit based royalty. For example, the ad valorem royalty rate for coal mining in New South Wales comprises three tiers according to the mine type – 7 per cent for opencut coal mines and, in recognition of the higher costs of developing and operating underground mines, 5 per cent for mines deeper than 400 metres and 6 per cent for other underground mines. In other cases, for example, an ad valorem royalty rate may vary according to a specified price range or increase annually over a specified number of years in the project life. In some instances, the arrangement includes a tax-free threshold or, if the resource is processed within the same jurisdiction, a reduced tax rate.
- Specific royalties generally apply to nonmetallic ore mining which includes high volume, low value nonmetallic minerals such as construction materials. The major exception in this industry is the application of ad valorem royalties to the mining of diamonds and other gemstones in several jurisdictions.

economic assessment of policy options

- From the economic analysis and project simulations in this study, it is apparent that extending a profit based royalty such as the Australian Government's petroleum resource rent tax to onshore mineral resources (possibly excluding low value nonmetallic minerals) is likely to result in significant efficiency gains, although this would be achieved at a higher administrative cost. The practical experience of the Australian Government in administering the petroleum resource rent tax is critical in the assessment of the administrative costs of such policy reform.

government tax take

- In practice, resource projects tend to vary widely in terms of the size and quality of the mineral resource ore deposit (ore deposit or fossil fuel field) both within any given time period as well as over time. In general, project profitability will vary with significant differences in the quality of ore deposits. The mix of resource projects will change over time as ore deposits are exhausted and new ore deposits are discovered and brought into production.

- Under a profit based royalty, the government aims to collect a constant percentage of the excess or supernormal profit of each resource project (that is, the resource rent). The government tax take is responsive to changes in project profitability, although the timing and magnitude of the government return will depend on the particular design of the profit based royalty.
- Under an output based royalty, an important problem facing policy makers is to set a royalty rate that is expected to collect sufficient royalty revenue to justify the imposition of the royalty but to make a subjective judgment about the negative impact on the profitability of low profit or marginal resource projects and the possible shortfall in returns from high profit projects.
- Provided there exists a range of low profit and high profit resource projects, output based royalties tend to overtax low profit projects and to undertax high profit projects. Compared with profit based royalties, the government tax take will be too high for low profit projects with some becoming uneconomic as a consequence (and the government tax take reduced to zero for these projects), and too low for high profit projects.

project profitability assessments by private investors

- Private investment decisions are assumed to be influenced by the perceived risks in potential resource projects as well as the attitudes of private investors toward incurring these risks. Risk averse private investors are generally assumed to adopt a relatively conservative approach in assessing the profitability of potential resource projects.
- In the economic framework adopted in this study, the decision rule for project profitability assessments by risk averse private investors is based on the certainty equivalent value – that is, the expected net present value of a resource project less a risk premium that provides private investors with sufficient compensation for incurring risk. A resource project is assessed to be profitable if the certainty equivalent value is non-negative (zero or positive). The valuation of the risk premium may therefore have an important influence on the assessment of project profitability.

risk premium

- An important feature of profit based royalties is that private investors share part of the risk of resource projects with governments. The extent of risk sharing depends on the design of the profit based royalty. A resource rent tax with full loss offset is similar to the Brown tax where the government is essentially a silent partner in the project (contributing the tax rate, for example 40 per cent, to the investment costs and receiving the tax rate applied to profits as a return on this investment). Under a resource rent tax, full loss offset is achieved when the net losses from failed resource projects are deductible against the profits from successful resource projects (this may occur through cash rebates, trade in losses between companies and/or companywide deductibility of losses).
- Under the petroleum resource rent tax, the tax rate of 40 per cent provides private investors with significant incentives to pursue profit opportunities in the industry, while allowing the government to collect a reasonable share of the resource rent. However, the petroleum resource rent tax does not provide full loss offset. The system allows companywide deductibility of exploration expenditure – the risk of losses from failed exploration projects by new companies and failed development projects by all companies is accounted for, to some extent, by incorporating a risk premium in the fiscal settings (the threshold rate and/or the accelerated rate of deduction for different expenditure categories).
- A resource rent tax with less than full loss offset still provides significant risk sharing between the government and private investors since the resource rent tax is not triggered until private investors achieve the threshold rate of return. The government then collects a percentage (the tax rate) of annual profits in excess of the threshold return to private exploration and capital expenditure.
- By contrast, under an ad valorem royalty, the government collects a constant percentage (the royalty rate) of the annual value of production irrespective of the net cash flow position of the project. In practice, the market price of the resource over the project life is a major source of risk for private investors and the ad valorem royalty is responsive, at least to some extent, to changes in market price. However, the government receives royalty payments in all years in which production from the resource project is positive, including any years in which losses may unexpectedly occur. As a consequence, the risk premium for any given project tends to be higher under an ad valorem royalty than would have been the case before the resource tax is applied.

risk adjusted project profitability – certainty equivalent value

- Compared with the outcome under profit based royalties, the certainty equivalent value (CEV) under an ad valorem royalty tends to be higher for high profit projects (since these tend to be undertaxed) and lower for low profit projects (since these tend to be overtaxed). As a consequence, a resource project is more likely to switch from being economic before tax (CEV≥0) to uneconomic after tax (CEV<0) under an ad valorem royalty than under any of the profit based royalties.
- These results reflect the net outcome of the government tax take and the risk assessment:
  - Under ***profit based royalties***, the government tax take varies with project profitability and the risk premium is reduced compared with the before tax outcome (reflecting the risk sharing characteristics of profit based royalties).
  - Under *an* ***ad valorem royalty***, the government tax take varies with the value of production (but not with project profitability) and the risk premium tends to be higher than the before tax outcome – there is some tendency, depending on the royalty rate, for an ad valorem royalty to overtax low profit projects and undertax high profit projects.

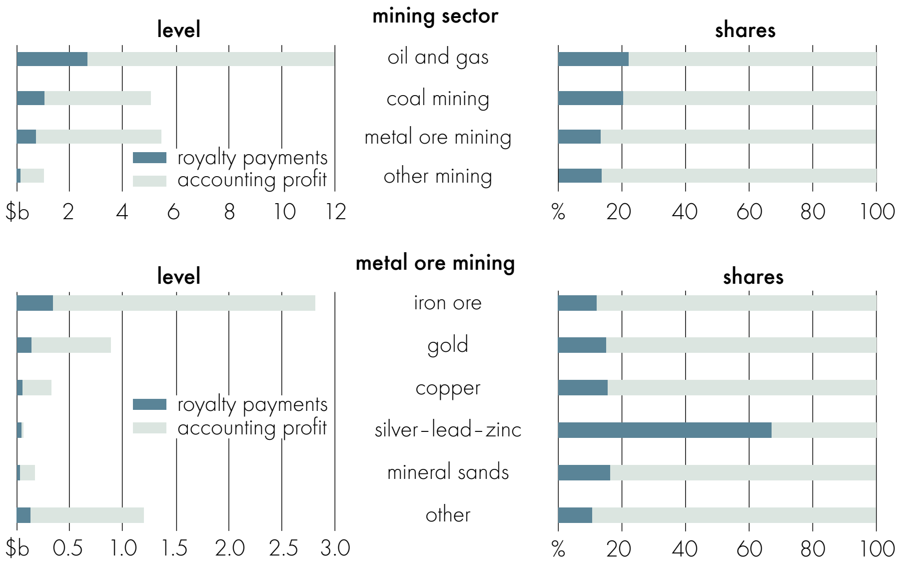
implications for resource taxation policy

- To assess the net economic benefits of extending a profit based royalty such as the petroleum resource rent tax to onshore mineral resources, the expected efficiency gains and the value of the resource rent collected through a mineral resources rent tax need to be compared with the likely increase in administrative costs. A significant advantage of a mineral resources rent tax designed along the lines of the petroleum resource rent tax is that it would be applied on a consistent basis to onshore mineral resources in Australia, replacing the current complex arrangements that have evolved over time across several jurisdictions.
- ABS data for 2002-03 provide an indication of the return to government and industry from the extraction of Australia's mineral resources. Resource royalty payments from Australia's mining sector were $4.5 billion in 2002-03 (ABS 2004; note this mainly comprises resource royalty payments, but also includes payments under mineral lease arrangements). There was significant industry variation in resource royalty payments in 2002-03 – $2.7 billion (or 58 per cent of the total) from oil and gas extraction, $1.0 billion (23 per cent) from

coal mining, $0.7 billion (16 per cent) from metal ore mining and $0.1 billion (3 per cent) from other mining (or nonmetal ore mining).

- Notably, the resource royalty payments from nonmetal ore mining are likely to be sourced mainly from a relatively small number of resources and mine sites (for example, the Argyle diamond mine is an important resource project in this category – see also the ABS value of production data in appendix A for an indication of the relative importance of different nonmetallic minerals). Resource rents for many nonmetallic minerals (such as construction materials) may be insufficient to justify consideration of the introduction of a profit based royalty with its higher administrative costs. Instead, an option in this category may be to apply a mineral resources rent tax to specific nonmetallic resources (such as diamonds and gemstones) that are assessed to earn sufficient resource rent.
- The distribution of mining profit to governments (through resource royalty payments) and industry (through accounting profit) in 2002-03 is indicated in figure A. The government share of mining profit in Australia's mining sector was 19 per cent in 2002-03 – 22 per cent for oil and gas extraction, 20 per cent for coal mining and 13 per cent for both metal ore mining and nonmetal ore mining. Notably, in the silver–lead–zinc ore mining industry, around 67 per

fig A **distribution of mining profit to industry and governments in Australia, 2002-03**



cent of mining profit was collected by the government through resource royalty payments – this may highlight the lack of responsiveness of output based royalties to annual variation in project profitability.

- The ad valorem royalty system in the New South Wales coal industry attempts to proxy a profit based royalty by applying different ad valorem royalty rates to different segments of the industry, based broadly on cost structures. In general, however, the higher the ad valorem royalty rate, the greater the negative impact on exploration and investment decisions in the industry.
- The share of the mining profit collected by governments in 2002-03 was significantly lower in the metal ore mining and nonmetal ore mining industries where output based royalties generally apply. This may indicate that governments have been willing to collect a smaller share of the resource rent in the metal ore mining and nonmetal ore mining industries to reduce the negative impact of output based royalties on marginal or low profit resource projects in these industries.
- The diversity in resource projects in Australia provides an indication of the difficulties facing policy makers in assessing the tradeoff between overtaxing low profit projects and undertaxing high profit projects under output based royalties.
- There is the potential for significant efficiency gains under a profit based royalty since royalty payments would only be made when the project has earned profits in excess of a threshold rate of return. Resource rent is likely to be higher under a profit based royalty than under an output based royalty.
- Overall, the petroleum resource rent tax is a competitive and efficient resource taxation system that has enabled the Australian Government, on behalf of the community, to collect a reasonable share of the resource rent in areas where this arrangement applies.
- Given Australia's substantial mineral resource assets, it is likely that there would be significant net economic benefits in extending a profit based royalty such as the petroleum resource rent tax to onshore mineral resources. The possible exception to this arrangement may be low value high volume nonmetallic minerals – apart from selected nonmetallic minerals such as diamonds and gemstones, resource rent in the nonmetal ore mining industry may be insufficient to justify the introduction of a profit based royalty with its higher administrative costs. Importantly, given its extensive experience in administering the petroleum resource rent tax, the Australian Government is well positioned to make a judgment about the expected administrative and transitional costs associated with extending a profit based royalty to onshore mineral resources in Australia.

1

introduction

Australia is a leading nation in the production and export of a wide range of mineral resources, including energy commodities, such as coal, LNG and uranium, and mineral commodities, such as iron ore, gold, base metals (copper, lead, zinc), nickel, mineral sands and diamonds (ABARE 2006b). In 2005-06, the value of Australia's mineral resources exports is estimated to have been around $92 billion (ABARE 2006a).

By international standards, Australia has substantial natural wealth in the form of mineral resources (Geoscience Australia 2005; Petrie and others, Geoscience Australia 2005). Notably, Australia is well endowed with a large number of mineral resources that are used in a range of industries – Australia's share and ranking in world economic demonstrated resources (EDR) in 2004 are presented in table 1 (the selected mineral resources are all significant in terms of value of production, as given in appendix A).

In Australia, mineral resources in the ground are owned by the community. The government, on behalf of the community, transfers exploration and production rights to the private sector in return for some payment – this payment is usually referred to as a resource tax or royalty (these terms are used interchangeably throughout this report). In 2004-05, resource royalty payments to governments were around $5 billion in the mining sector (MCMPR 2006).

The Australian Government is responsible for oil and gas resources located offshore outside the three nautical mile territorial sea limit as well as for uranium resources in the Northern Territory. State and territory governments are responsible for other mineral resources located in their respective jurisdictions.

An issue that has been increasingly recognised in recent years by governments and industry participants is the diversity of resource taxation arrangements in Australia. In particular, resource taxation arrangements may vary within a given jurisdiction for different mineral resources as well as between jurisdictions for the same mineral resource. In some instances, a mineral resource may be subject to different arrangements within the one jurisdiction.

At a meeting in July 2004, the Ministerial Council for Mineral and Petroleum Resources (MCMPR) directed its Standing Committee of Officials (SCO) to examine and report on the competitiveness of the fiscal environment in which

Australia's mineral and petroleum industries operate (MCMPR 2006). Resource taxation arrangements are an important component of this fiscal environment.

The objective in this report is to provide an economic assessment of resource taxation policy options in Australia's mining sector. In broad terms, resource taxation policies may be classified according to whether they are based on the profit or production of a resource project:

- *Profit based royalties* are levied on the net cash flow or profit of a resource project – for example, a resource rent tax is levied as a constant percentage of a project's net cash flow (whereby exploration and general expenditures are accumulated at some threshold rate and offset against future revenues).
- *Output based royalties* are levied on the volume or value of production of a resource project – for example, a specific royalty is levied as a constant (dollar) amount per physical unit of production and an ad valorem royalty is levied as a constant percentage of the value of production.

The resource taxation arrangements that apply in Australia are mainly specific and ad valorem royalties, although the Australian Government's petroleum resource rent tax is an important example of a profit based royalty. In many jurisdictions, variants of these basic royalty arrangements exist. For example, an ad valorem royalty rate may vary according to a specified price range or increase annually over a specified number of years in the project life. In some instances, the arrangement includes a tax-free threshold or, if the resource is processed within the same jurisdiction, a reduced tax rate.

Since the late 1980s, ABARE has undertaken a number of economic assessments of resource taxation policies, with some focus on Australia's offshore petroleum resources. Hinchy, Fisher and Wallace (1989) provided a theoretical analysis of mineral taxation policy, with an emphasis on the implications of uncertainty and risk in mineral exploration, development and production. To complement this analysis, Hogan and Thorpe (1990) simulated the impact of several alternative resource taxation arrangements on a wide range of hypothetical risky oil and gas projects that were assumed to be broadly representative of the Australian petroleum industry. The distortions to private investment and production decisions caused by the explicit and implicit resource tax regime in the Queensland coal industry were highlighted by Thorpe, Anthony and Croft (1990). More recently, Hogan and Donaldson (2000) noted the wide variation in resource taxation arrangements in Australia's minerals industry and Hogan (2003) examined fiscal settings in Australia's petroleum resource rent tax.

There are two key aspects to the economic analysis of alternative resource taxation arrangements in this study. First, the economic implications of resource taxation policy options for industry production and profitability are examined. Second, the impact of selected key policy options on a number of hypothetical resource projects is quantified.

The main criteria used in the economic assessment of alternative resource taxation arrangements are economic efficiency, which refers to the extent to which private investment and production decisions are distorted by the resource tax policy, and administrative costs. A major focus in this study is to assess the costs and benefits of extending the profit based royalty from the offshore petroleum regime to the several mineral resources regimes onshore.

In chapter 2, the main features of current resource taxation arrangements in Australia are summarised. The economic rationale for resource taxation and the economic implications of alternative resource taxation arrangements are examined in chapter 3. The simulations of alternative resource taxation options on hypothetical resource development projects are provided in chapter 4. Some key implications of the analysis for Australia's current resource taxation policy arrangements are discussed in chapter 5.

table 1 **Australia's share and ranking in selected world economic demonstrated resources** as at December 2004

	share	ranking
	%	no.
oil and gas a		
oil	0.3	28
natural gas	1.4	14
coal		
black coal	5	6
brown coal	24	1
selected metallic minerals		
iron ore	9	5
gold	12	2
base metals and nickel		
– copper	9	2
– lead	26	1
– zinc	18	1
– nickel	37	1
mineral sands		
– ilmenite	20	2
– rutile	39	1
– zircon	41	1
bauxite	–	2
uranium	40	1
tantalum	95	1
manganese	11	4
tin	–	10
silver	15	2
selected nonmetallic minerals		
diamonds		
industrial	10	4
gem/near gem quality	–	high

a Based on BP statistics for proved reserves of oil and natural gas. Oil includes crude oil, condensate and LPG. Natural gas includes gas that may be processed into LNG for transport purposes. In Petrie and others, Geoscience Australia (2005), Australia's share in world gas reserves is estimated to have been 2.6 per cent at the end of 2002.
Sources: BP (2005); Geoscience Australia (2005).

2

resource taxation arrangements in Australia's mining sector

Australia has a 200 nautical mile Exclusive Economic Zone (EEZ) around continental Australia and its territories in accordance with the United Nations Convention on the Law of the Sea (UNCLOS). The Australian Government is responsible for mineral resources in Australia's offshore areas beyond three nautical miles as well as for uranium in the Northern Territory. In all other cases, mineral resources located in coastal waters – areas in the zone within three nautical miles of the coast – or on land are the responsibility of the corresponding state or territory government.

Australia's mining sector is defined to include both petroleum and minerals industries. Traditionally, output based royalties have been applied in Australia's mining sector by federal, state and territory governments, largely reflecting the administrative simplicity of these arrangements compared with profit based royalties. Over the past two decades, there have been a number of important policy developments including, most notably, the introduction of the petroleum resource rent tax in 1987. However, there continues to be considerable variation in resource taxation arrangements between different jurisdictions and, in many cases, within a jurisdiction.

In this chapter, an overview of the resource taxation arrangements that apply in Australia's mining sector is provided. Given the complexity of the current system, resource taxation arrangements are outlined separately according to the resource groupings given in table 1 and appendix A:

- *oil and gas* – based on ABS data, the value of production was $16.4 billion in 2002-03
- *coal* – the value of production was $13.3 billion in 2002-03
- *metallic minerals* – the value of production was $19.0 billion in 2002-03
- *nonmetallic minerals* – the value of production was $3.0 billion in 2002-03.

ABS value of production data provide a useful indication of the relative importance of a wide range of mineral resources in different jurisdictions – detailed data for 2002-03 are provided in appendix A based on ABS (2004). ABS estimates the value of production in Australia's mining sector was $51.7 billion in 2002-03.

oil and gas

An overview of resource taxation arrangements for Australia's oil and gas resources is provided in table 2. The major oil and gas producing areas are offshore in north west Australia (mainly the Carnarvon basin) and Bass Strait (Gippsland basin), and onshore in the Cooper–Eromanga basin (Queensland and South Australia) (see ABARE 2006c for detailed information; a map providing

table 2 **resource taxation arrangements for petroleum in Australia** a

	royalty or tax rate			
jurisdiction	**specific**	**ad valorem**	**profit**	**comment**
	$	%	%	
Australian Government				
Petroleum resource rent tax (PRRT)			40	Applies to offshore areas under the jurisdiction of the Australian Government, excluding the North West Shelf (NWS) permit area and the Joint Petroleum Development Area (JPDA); see text for details
Barrow Island			40	Resource rent royalty (RRR); revenue shares – 75% to the Australian Government and 25% to the Western Australian Government
NWS permit area				Royalty rates applied to the wellhead value. Revenue shares – 60–68% to the Western Australian Government and the remainder to the Australian Government
– primary licences		10.0		
– secondary licences		11.0–2.5		
Crude oil excise				First 30 million barrels of production is exempt from the excise. Increasing scale based on annual crude oil production, date of discovery and production start date; applies onshore, in coastal waters and to the offshore NWS permit area
– new		0–35		
– intermediate		0–55		
Joint Petroleum Development Area (JPDA)				Mix of arrangements apply under a production sharing contract (PSC) between the East Timor government and the Australian Government; see MCMPR (2006) for details

continued...

table 2 **resource taxation arrangements for petroleum in Australia** a
continued

	royalty or tax rate			
jurisdiction	specific	ad valorem	ad profit	comment
	$	%	%	
Western Australia				
– primary licences		10.0		
– secondary licences		11.0 – 12.5		
Queensland		10.0		
New South Wales				
Titles granted or renewed after 21 August 1992		0 – 10.0		Ad valorem royalty first applies in sixth year of production at a rate of 6%, increasing by 1% each year to 10% in year 10
Other titles		10.0		
Victoria		10.0		
Northern Territory		10.0		
South Australia		10.0		

a Excludes Tasmania, where petroleum production is zero.

the location of each basin is given in Geoscience Australia 2005). Some care should be taken in interpreting the ABS value of production data in appendix A since the ABS assigns all offshore production to the adjacent state or territory.

The petroleum resource rent tax (PRRT) applies to offshore areas under the jurisdiction of the Australian Government, excluding the North West Shelf (NWS) permit area and the Joint Petroleum Development Area (JPDA). The petroleum resource rent tax is levied at a rate of 40 per cent of net project income after accumulated general project expenditures have been deducted. General project expenditure is accumulated at the long term government bond rate plus 5 percentage points. Exploration expenditure is transferable between projects within the same company and is immediately deductible.

In the 2004-05 federal budget, the Australian Government announced the introduction of an immediate uplift to 150 per cent for exploration expenditure in designated offshore frontier areas in recognition of the greater risks associated with exploration activity in these areas – the government will apply the concession for five years to no more than 20 per cent of each annual acreage release. For new companies, undeducted exploration expenditure is accumulated at the long term bond rate plus 15 percentage points if the expenditure is incurred within five years of the lodgment date of data required for the granting of the production licence; otherwise, the exploration expenditure is maintained in real terms (that is, accumulated at the GDP inflation factor).

A profit based royalty arrangement also applies to the Barrow Island project under a joint arrangement by the Australian and Western Australian Governments.

In the NWS permit area, output based royalty arrangements apply, with ad valorem royalty rates generally in the range of 10.0–12.5 per cent and a crude oil excise that is applied at a rate that increases with crude oil production. The first 30 million barrels of production is exempt from the excise.

coal

An overview of resource taxation arrangements for Australia's coal resources is provided in table 3. Black coal is produced mainly in Queensland and New South Wales for domestic electricity generation and the export market. Brown coal, which is lower quality than black coal, is produced in Victoria for electricity generation.

An ad valorem royalty applies at a rate of 7 per cent for all coal mines in Queensland and for opencut coal mines in New South Wales. A lower rate applies to underground coal mines in New South Wales in recognition of the higher costs of developing and operating these mines – the rate is 5 per cent for mines deeper than 400 metres and 6 per cent for other underground mines.

In Victoria, a specific royalty applies to brown coal production based on the energy content of the coal. Effective 1 January 2006, the specific royalty rate is $0.0588 per gigajoule and is adjusted annually for inflation (as measured by the consumer price index).

In Western Australia, a specific royalty applies to coal produced for the domestic market (adjusted annually in line with changes in a benchmark coal price) and an ad valorem royalty applies to exported coal (at a rate of 7.5 per cent).

Resource taxation arrangements in other jurisdictions are the same as would apply for metallic minerals. Most notably, in South Australia, an ad valorem royalty applies at a rate of 2.5 per cent. Since coal production is low in Tasmania (based table 3 **resource taxation arrangements for coal in Australia a**

	royalty or tax rate			
jurisdiction	**specific**	**ad valorem**	**profit**	**comment**
	$	%	%	
Western Australia				
not exported	$1.00/t			Adjusted annually by percentage change since 1981 in ex mine value of Collie coal
exported		7.5		
Queensland		7.0		
New South Wales				
underground				
– deep (>400 metres)		5.0		
– other		6.0		
open cut		7.0		
Victoria b	$0.0588/GJ			Based on energy content; adjusted annually for inflation; see MCMPR (2006) for details
South Australia		2.5		Based on assessed value
Tasmania		1.6–5.0	*	Hybrid ad valorem/profit based royalty: 1.6% of net sales plus component based on profit with a cap of 5% of net sales; 20% rebate if processing in Tasmania

a Excludes the Northern Territory where coal production is zero. **b** Brown coal where mines are co-located with power stations.

on data in ABARE 2006c) and zero in the Northern Territory, the royalty arrangements in these jurisdictions are outlined in the next section.

metallic minerals

An overview of resource taxation arrangements for Australia's metallic mineral resources is provided in table 4. Western Australia is the largest producer of several key metallic minerals including iron ore, gold, nickel, mineral sands and bauxite (note the ABS value of production data in appendix A do not include bauxite production in Western Australia; see ABARE 2006c for production data). Queensland is the largest producer of base metals (copper, lead, zinc) and also produces a range of other metallic minerals including gold, bauxite and mineral sands. New South Wales mainly produces base metals and gold. Several metallic minerals are produced in the Northern Territory, South Australia and Tasmania – uranium, an important energy commodity, is produced in the Northern Territory and South Australia. Gold is the only metallic mineral that is produced in all jurisdictions.

An ad valorem royalty system applies in most jurisdictions. In Western Australia, the ad valorem royalty rate varies according to the extent of processing – 7.5 per cent for bulk material (including bauxite), 5 per cent for concentrate material (including mineral sands) and 2.5 per cent for metal. However, the ad valorem royalty rate is halved to 1.25 per cent for gold production if the market price falls below A$450 an ounce.

In Queensland, an ad valorem royalty generally applies at a fixed rate of 2.7 per cent, although producers also have the option of choosing a variable rate after mining has commenced that will be effective for a five year period. The variable rate will be between 1.5 per cent and 4.5 per cent, depending on market price movements – that is, the rate is an increasing scale based on price. The first $30 000 is exempt from the royalty, and royalty payments are reduced by 20–35 per cent if the mineral is processed in Queensland. Key exceptions to this arrangement are bauxite and mineral sands where an ad valorem royalty of 5 per cent applies (a 10 per cent royalty applies to bauxite if it is not processed in Queensland).

Ad valorem royalties apply in New South Wales (4 per cent), South Australia (2.5 per cent) and Victoria (2.75 per cent). However, different arrangements apply at the Broken Hill 'line of lodes' mines in New South Wales, and metallic mineral production in South Australia is mainly sourced from the Olympic Dam project which is subject to a royalty of 3.5 per cent. In addition, Victoria's metallic mineral production is essentially sourced from gold (low quantities of mineral sands have been produced in Victoria; see ABARE 2005b) – no royalty applies to gold production in Victoria.

In Tasmania, an ad valorem royalty applies at a rate between 1.6 per cent and 5.0 per cent depending on profit outcomes – that is, the rate is an increasing scale based on profit. A 20 per cent rebate applies if the mineral is processed in Tasmania.

table 4 **resource taxation arrangements for metallic minerals in Australia**

resource/ jurisdiction	royalty or tax rate specific $	ad valorem %	profit %	comment
general approach				
Western Australia				
– ore (bulk material)		7.5		
– concentrate		5.0		
– metal		2.5		
Queensland				Option of fixed or variable rate for prescribed minerals (includes base metals and gold); the first $30 000 is not liable to royalty; royalty payments reduced by 20–35% if processing in Queensland, depending on mineral
– fixed rate		2.7		
– variable rate		1.5-4.5		Increasing scale based on market price
New South Wales		4.0		Ex mine value (value less allowable deductions)
Victoria		2.75		
Northern Territory			18	Based on net value of production where the first $50 000 is not liable to royalty
South Australia		2.5		Based on assessed value
Tasmania		1.6-5.0	*	Hybrid ad valorem/profit based royalty: 1.6% of net sales plus component based on profit with a cap of 5% of net sales; 20% rebate if processing in Tasmania
key exceptions or further information to above				
iron ore				
Western Australia				
– lump ore		7.5		
– fine ore		5.625		
– beneficiated ore		5.0		
gold				
Western Australia				
– price ≥ A$450/oz		2.5		
– price < A$450/oz		1.25		
Victoria		0		
South Australia		3.5		New mines may qualify for a rate of 1.5 per cent for the first five years

continued...

table 4 **resource taxation arrangements for metallic minerals in Australia**

continued

resource/ jurisdiction	royalty or tax rate: specific $	ad valorem %	profit %	comment
mineral sands				
Western Australia		5.0		
Queensland		5.0		
bauxite				
Western Australia		7.5		
Queensland		10.0		5% royalty if processing in Queensland
Northern Territory				See Alcan bauxite below
uranium				
Northern Territory		5.5		Under jurisdiction of the Australian Government; applies to the Ranger uranium mine; see text for details
South Australia		2.5		See Olympic Dam below
project specific arrangements				
New South Wales				
Broken Hill 'line of lodes'				Profit based royalty
South Australia				
Olympic Dam		3.5		A surplus royalty may apply
Northern Territory				
Bauxite, Alcan		unknown		Commercial-in-confidence

In the Northern Territory, a royalty of 18 per cent of the net value of production applies where the first $50 000 is exempt from the royalty. The details of the arrangements that apply at the Alcan bauxite and alumina operation in Gove are commercially protected and hence are not publicly known.

Uranium production in the Northern Territory is under the jurisdiction of the Australian Government. The Ranger uranium mine is subject to a 5.5 per cent ad valorem royalty, comprising a 4.25 per cent payment to the Aboriginal Benefit Account and a 1.25 per cent payment to the Northern Territory Government in lieu of royalties. No other uranium mines currently operate in the Northern Territory.

table 5 **resource taxation arrangements for selected nonmetallic minerals in Australia**

	royalty or tax rate			
jurisdiction	specific	ad valorem	profit	comment
	$	%	%	
Western Australia				
Diamonds and other gemstones		7.5		See specific projects listed below
– other amount A	$0.30/t			Rate in 2004-05; annual increases announced to $0.50/t in 2009-10. For example, applies to salt, limestone for nonmetallurgical use, clays, dolomite, gravel, gypsum and sand
– other amount B	$0.50/t			Rate in 2004-05; annual increases announced to $0.80/t in 2009-10. For example, applies to limestone for metallurgical use, building stone, silica and talc
Queensland				
salt	$1.00/t			
limestone	$0.30/t			
phosphate rock	≥$0.80/t			Maximum of either $0.80/t or a rate based on P_2O_5 content and specified market price
clay shale	$0.25/t			
marble	$0.50/t			
New South Wales				
diamonds and other gemstones		4.0		Ex mine value (value less allowable deductions)
limestone	$0.40/t			
clay shale	$0.35/t			
dimension stone	$0.70/t			
Victoria		2.75		
Northern Territory				
construction materials				
other			18	Based on net value of production where the first $50000 is not liable to royalty
South Australia		2.5		Based on assessed value
Tasmania	$1.20/t			
project specific arrangements				
Western Australia				
Argyle Diamond mine		5.0		Effective from 1 January 2006
Ellendale Diamond project		7.5	22.5	Combined ad valorem/profit based royalty: 7.5 per cent ad valorem royalty, or 22.5 per cent accounting profit royalty if greater

nonmetallic minerals

An overview of resource taxation arrangements for Australia's nonmetallic mineral resources is provided in table 5. New South Wales, Queensland, Victoria and to a lesser extent South Australia are the main jurisdictions for the production of construction materials. Based on ABS value of production data, the most important nonmetallic minerals produced other than construction materials are diamonds, salt, limestone, phosphate rock and opals. Western Australia is the most important producer of other nonmetallic minerals, mainly diamonds and salt. Phosphate rock is a significant resource in Queensland, and opals are produced in both New South Wales and South Australia. Limestone is produced in most jurisdictions.

Specific royalties are applied to a wide range of nonmetallic mineral resources in Western Australia, Queensland, New South Wales and Tasmania – rates tend to vary between resources and jurisdictions. Notably, diamonds and other gemstones are subject to an ad valorem royalty in Western Australia (7.5 per cent) and New South Wales (4 per cent), although other arrangements apply to the Argyle and Ellendale diamond projects in Western Australia (the royalty rate was reduced to 5 per cent for the Argyle diamond mine, effective from 1 January 2006).

The same ad valorem arrangements apply to metallic and nonmetallic mineral resources in Victoria, the Northern Territory (excluding construction materials) and South Australia.

It should be noted that the aim in this chapter has been to present the key features of the resource taxation arrangements that currently apply in Australia's mining sector. Arrangements are also subject to change. More detailed information is available in MCMPR (2006) – see also the websites of the relevant government departments for mineral resources.

3

economic aspects of resource taxation policy

The aim in resource taxation policy is to enable the government to collect a reasonable return on the use of the community's mineral resources, while ensuring that administrative costs are not excessive and industry outcomes remain relatively efficient. It is evident from the previous chapter that a wide range of resource taxation arrangements currently apply in Australia. Given the complexity of these arrangements, it is useful to base any economic assessment, at least initially, on a limited number of key resource taxation policy options that include both output based royalties and profit based royalties. The implications of this analysis for current policy approaches may then be considered by policy makers.

In this chapter, the economic rationale for resource taxation is discussed and the economic implications of key resource taxation options for industry outcomes is examined using a simplified supply–demand framework.

economic rationale for resource taxation

The economic rationale for resource taxation is based on the presence of resource rent in the mining sector. Each input to a productive process earns a return – for example, owners of capital earn profit, owners of land earn rent and workers earn a wage or salary in return for the provision of their labour services. Similarly, it is reasonable that owners of mineral resources should expect to earn a return from the extraction of resources.

resource rent

Resource rent is typically assumed to be equal to economic rent in the mining sector. The economic rent in an economic activity is the excess profit or super-normal profit earned in a competitive market, and is equal to the excess of revenue over costs where costs are defined to include a 'normal' rate of return on capital. This normal rate of return may be interpreted to be the minimum rate of return required to hold capital in the activity, and includes an allowance for a risk premium since private investors are usually assumed to be risk averse (see, for example, Hinchy, Fisher and Wallace 1989). Attitudes toward risk and the profitability assessments of risky projects are discussed more formally in chapter 4.

The concept of resource rent in the mining sector applies over the longer term and, importantly, takes into account the following distinct economic activities:

- *production* – the cost of extracting resources from established mine sites (including abandonment costs such as mine site rehabilitation costs)
- *new resource developments* – the cost of producing ore from new resource developments based on mineral ore deposits that are known
- *exploration* – the cost of finding new mineral ore deposits.

Resource rent in the mining sector may persist in the long run due to the quality or scarcity value of different ore deposits or fossil fuel fields (for simplicity, any references in this report to ore deposits and mine sites also apply to fossil fuel fields and petroleum projects).

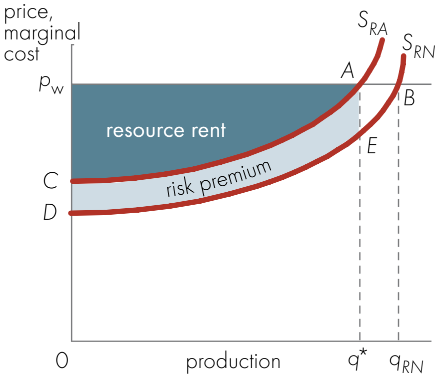
- The ***quality rent*** is associated with the quality differential of ore deposits – the marginal cost of extraction tends to be lower for higher quality (more productive) ore deposits and, as a consequence, for a given price, higher quality ore deposits earn a larger excess of revenue over costs than marginal ore deposits.
- The ***scarcity value*** of the resource reflects the opportunity cost of future production forgone when the resource is extracted in the current period – that is, if investors choose to extract the resource now, the value of doing so must be at least equal to the value of choosing to extract in some future period.

The concept of resource rent is illustrated in figure B where, for simplicity, price is assumed to be determined on world markets at p_w. The long run industry supply curve, S_{RA}, represents the long run marginal cost of exploration, development and production (including abandonment) where private investors are assumed to be risk averse (*RA*). Given this industry supply curve and the world price, the equilibrium position for the industry occurs at point *A,* with output given by q^*. It would not be profitable for the industry to incur any additional costs by increasing activity beyond this level – in addition, there would be unexploited profit opportunities if activity stopped at a lower level.

Total industry revenue is given by the area $0p_wAq^*$ (equal to the world price multiplied by output, or p_wq^*). Total industry costs are given by the area under the supply curve, *0CAq**, noting that this includes the risk premium to compensate private investors for the risks incurred in the activity. The resource rent, assumed to be equal to the economic rent, is the profit in excess of the industry's normal return and is given by the area Cp_wA.

In the discussion on resource rent tax options, it will be important to identify the industry's risk premium. For this reason, figure B explicitly includes the industry supply curve, S_{RN}, that would exist if private investors were risk neutral (*RN*). Given this hypothetical industry supply curve and the world price, the equilibrium position for the risk neutral industry occurs at point *B* with output given by q_{RN}. The industry's risk premium is the difference between the two supply curves up to the industry output, q^*, and is given by the area, *ACDE*.

fig B **illustrative long run industry supply and resource rent**



In the presence of risk and risk averse private investors, industry output is lower than would otherwise be the case since a number of marginal projects are assessed to be too risky to be undertaken given future possible outcomes relating to the geological, economic and policy environments.

criteria for policy assessment

In Australia, mineral resources are assumed to be owned by the community. The relevant government, on behalf of the community, is responsible for managing this natural resource asset. The presence of resource rent in the mining sector provides governments with the economic justification to consider options whereby exploration and production rights are transferred to the private sector in return for a payment that does not exceed the resource rent.

The approach taken in any economic policy assessment is to examine the benefits, costs and risks of alternative policy options that should be ranked according to expected net economic benefits. In principle, the resource taxation option with the highest expected net economic benefits (or lowest expected net economic cost in the current study) is preferred to the alternatives. In practice, it may be difficult to identify and quantify all significant economic effects and some aspects of the assessment will rely on the subjective judgment of policy makers. In this study, resource taxation policy options are examined within a relevant economic framework as an input to the policy making process.

The objective in resource taxation policy is assumed to be to collect a reasonable share of the resource rent at least cost, where costs may include administrative costs and losses incurred through negative distortions to private exploration and development decisions. That is, resource taxation policy options are assessed on the basis of administrative costs and economic efficiency.

Administrative costs are the costs associated with revenue collection under the resource taxation policy, including monitoring the compliance of private investors in meeting their obligations under the policy. Costs are incurred by both private investors and government. In general, the administrative costs of a resource taxation policy tend to be higher if the information requirements of the policy are higher. An assessment of the costs associated with the transition to any change in current arrangements is beyond the scope of this study, but is clearly an issue for policy makers.

Economic efficiency refers to the extent to which the resource taxation policy has a negative impact on private exploration, development and production decisions such that the profitability assessments of resource projects are fundamentally changed in some way – this is discussed further below under neutrality of resource tax policy. An important aspect of efficiency is the extent to which a policy option is responsive to changes in the geological, economic and broader policy environment over time. A policy option that requires governments to adjust fiscal settings in response to major changes in market conditions would not be considered to be an automatic response to economic change. The increase in sovereign risk and administrative costs associated with the potential for governments to adjust fiscal settings over time (as occurs with output based royalties) would need to be taken into account in the economic assessment of policy options.

neutrality of resource taxation policy

Consideration of the neutrality of resource taxation policy has been an important feature of previous economic assessments. It is useful to distinguish two concepts of neutrality:

- *a tax is weakly neutral* if it does not alter the rankings of alternative risky projects for an investor

- *a tax is strongly neutral* if it satisfies weak neutrality and does not change the decisions of investors relating to which projects will proceed and which do not (that is, it does not change the cutoff point between projects that would be undertaken and those that would not).

Hinchy, Fisher and Wallace (1989) discuss the issue of whether these criteria need to be modified in the presence of risk when there are imperfect risk markets (including futures, insurance, capital and equities markets). When investors are risk averse, there may be a suboptimal level of investment in higher risk projects (that is, risk averse investors may discriminate against higher risk projects). The efficiency of resource allocation may therefore be improved by changing the preference rankings of investors.

Any bias in policy, if at all appropriate, would be toward encouraging firms to undertake more risky activities. Nevertheless, the neutrality criteria are important benchmarks against which to assess alternative resource taxes, and the direction of any distortion in preference rankings.

key resource taxation policy options

It is the presence of resource rent that justifies consideration of resource taxation policy options. The resource rent is the return to the mineral resource. The objective in resource taxation policy is to enable the government to obtain some payment in return for the extraction of the community's mineral resources. As indicated above, a resource taxation system should be designed to ensure that the government receives a reasonable share of the resource rent, taking into account administrative costs and the implications of the resource tax for private risk and profitability assessments of resource projects.

There is an important distinction between profit based royalties and output based royalties. Profit based royalties aim to collect a share of the resource rent while minimising any negative impacts on private investment and production decisions, while output based royalties generally represent a simplified approach to resource taxation policy since project cost data are not required in any assessment of annual resource tax obligations (although some knowledge of costs would be required in setting policy parameters).

It is interesting to note that a significant part of the complexity of current arrangements in Australia is the attempt in some jurisdictions to proxy a profit based royalty by adopting variants of output based royalties – for example, ad valorem royalty rates are reduced for a higher cost production process in the New South Wales coal industry. For simplicity, the economic assessment in this report focuses on a small number of key resource taxation options including:

- *profit based royalties* – the Brown tax and resource rent tax
- *output based royalties* – the ad valorem royalty and specific royalty (each levied at a constant rate).

The Brown tax is included in the discussion below because it is a useful benchmark against which to assess other policy options, particularly the resource rent tax. It should be emphasised that the Brown tax is not considered in this report to be a feasible policy option for implementation since it involves cash rebates to private investors.

profit based royalties

Brown tax

The Brown tax, named after a tax proposed by Brown (1948), is levied as a constant percentage of the annual net cash flow of a resource project with cash payments made to private investors in years of negative net cash flow. Net cash flow is defined as the difference between total revenue and total costs (which include all exploration and capital expenditure during the year). In years where net cash flow is negative, the government pays the investor the Brown tax rate multiplied by the losses. In years where net cash flow is positive, the government receives the same fixed proportion of the profits. The economic implications of a Brown tax, including implementation issues, are discussed in some detail in Hinchy, Fisher and Wallace (1989).

The Brown tax is a neutral resource tax policy if private investors are risk neutral. That is, with risk neutral private investors, the ranking of resource projects is unchanged and there is no switching between economic and uneconomic projects (see the discussion in the previous section on neutrality of tax policy).

The Brown tax essentially shares the risks of resource projects between private investors and the government. Given the risk sharing characteristics of the Brown tax, with risk averse private investors, it is possible that marginal projects will switch from being uneconomic before tax to economic after tax. In figure B, this implies that the risk premium is reduced for resource projects and, in particular, marginal projects may become profitable, in which case industry output would increase under a Brown tax (that is, output would be larger than q^*).

resource rent tax

The resource rent tax is a profit based royalty that was first proposed by Garnaut and Clunies Ross (1975) for natural resource projects in developing countries to enable more of the net economic benefits of these projects to accrue to the domestic economy. The resource rent tax is typically regarded as a practical alternative to the Brown tax since the government avoids the need for providing private investors with a cash rebate during years of negative net cash flow.

Under a resource rent tax, all losses are accumulated at a threshold rate and offset against future profits. The resource rent tax is triggered when the net cash flow, including accumulated costs, becomes positive. That is, the resource rent tax is only paid when a private investor achieves a threshold rate of return on the investment in the resource project. Investment in the project may be interpreted broadly to include both exploration expenditure required to discover the ore deposit (or fossil fuel field) and expenditure associated with the development of the mine site (or petroleum project) in preparation for mineral (or petroleum) production.

For risk neutral private investors, the threshold rate should be set at the risk free interest rate. For risk averse private investors, there is an issue relating to the inclusion of a risk premium allowance before the resource rent tax is triggered. The original resource rent tax proposed by Garnaut and Clunies Ross (1975) included a risk premium in the threshold rate of return. Hogan (2003) argued that a risk premium allowance to private investors may also be achieved by introducing an accelerated rate of deduction for expenditure.

Three features of the resource rent tax merit further consideration:

- *treatment of failed resource projects* – these are projects whereby expenditure has been incurred by private investors but the project makes a net loss; importantly, this includes exploration projects that fail to discover a significant mineral resource deposit (ore deposit or fossil fuel field)
- *appropriate risk premium allowance* – the issue is to what extent, if any, should a risk premium be included in the threshold rate and/or the accelerated rate of deduction

- *setting the tax rate* – the issue is what proportion of the resource rent (or economic rent more generally) should government attempt to collect through the resource rent tax.

These features are discussed below, although it should be emphasised that the settings are interrelated.

treatment of failed resource projects

As indicated earlier, resource rent in the mining sector is the excess of revenue over costs where costs include a normal rate of return to the investment – this was illustrated in figure B. A resource rent tax that is levied only on successful resource projects that achieve the threshold rate of return fails to fully account for all revenues and costs in the mining sector (that is, there is a lack of full loss offset in the resource rent tax).

The original approach suggested by Garnaut and Clunies Ross (1975) is for the resource rent tax to apply to individual resource projects where, importantly, exploration activity in a lease area would be treated as a distinct resource project. It was argued that a higher risk premium and/or lower tax rate than would otherwise apply would compensate industry for the lack of full loss offset.

The original petroleum resource rent tax introduced in Australia in the mid-1980s was project based. An important modification to the petroleum resource rent tax was introduced in 1990 to allow companywide deductibility of exploration costs in recognition that typically a private investor may undertake exploration in a number of lease areas before a significant discovery is made that leads to petroleum field development and production. The threshold rate, which had been set at a relatively high rate to compensate private investors for the lack of full loss offset, was reduced. In 2005, exploration expenditure in specified frontier areas was provided with a 150 per cent tax deduction in recognition of the importance of exploration activity in discovering new fossil fuel fields, and in particular a new offshore oil province, and the higher risks associated with this activity (see Hogan 2003, and Cuevas-Cubria and Riwoe 2006 for further information). A tax rate of 40 per cent has applied in the petroleum resource rent tax since its inception.

Various options have been identified in the economics literature to achieve full loss offset – these are discussed in Hinchy, Fisher and Wallace (1989). With companywide deductibility of exploration expenditures, lack of full loss offset occurs because of the taxation treatment of exploration projects by new companies in the industry and failed projects in the development and production stages. Consistent with the approach underpinning the design of the resource rent tax (and the observed preferences of governments), governments are assumed to prefer to avoid paying cash rebates for failed resource projects.

To achieve full loss offset in a resource rent tax while avoiding cash rebates, the main options are:

- to allow companies to transfer the loss of failed projects to successful projects within the same company
- for companies without successful projects against which to offset losses, to allow the sale of losses on failed projects to other companies with resource rent tax obligations.

An issue that would need to be considered in implementing a resource rent tax to mineral resources in Australia is the transferability of losses that would be allowed, if any, between jurisdictions.

threshold rate and risk premium allowance

As discussed above, full loss offset occurs when all relevant expenditures in exploration, development and extraction are offset against revenue for resource rent tax purposes. With full loss offset, the main objectives in setting the threshold rate and tax rate are often argued to be to target efficient investment outcomes and to collect a share of the economic rent, respectively. It will be apparent from the discussion below that there are significant issues in designing a resource rent tax, particularly in the inclusion of a risk premium allowance.

With risk neutral private investors, the appropriate threshold rate is the risk free interest rate that is typically assumed to be the long term government bond rate (LTBR). It may also be argued that the relevant discount rate in assessing the value of any future income, or reduced tax liability, that will occur with certainty is also this risk free interest rate (since there is no risk in achieving the future benefit to net cash flow).

- ***risk premium allowance***

In principle, if the threshold rate for a given project is set at the private investor's minimum rate of return (comprising the risk free interest rate plus an appropriate risk premium), the remaining net cash flow may be assumed to equal the resource rent of the project.

However, it is useful to note that a risk premium, as illustrated in figure B, may be provided to private investors through the resource rent tax as:

- a risk premium in the threshold rate, and/or
- a risk premium in the rate at which expenditures may be deducted (that is, an accelerated rate of deduction).

As Garnaut and Clunies Ross (1979, 1983) noted in the context of setting the threshold rate, if the risk premium is set above the true risk premium there may potentially be an incentive for overinvestment in the activity. Conversely, if the risk premium is set below the true risk premium, the resource rent tax has the potential to deter some projects that would otherwise have proceeded.

The risk premium in a resource project is dependent on the assessment by the private investor of the risks in the project as well as the investor's attitude toward risk – for example, some companies are more conservative, or risk averse, than other companies and will take a more cautious approach to investing in resource projects (these issues are discussed further in chapter 4). The private investor may be able to reduce the risk premium, at least to some extent, by adopting various risk reducing strategies such as participating in joint ventures.

Although there will be individual variation in risk assessments, it would be administratively complex, if not infeasible given the substantial asymmetries in information between the government and private investor, to apply a risk premium on a project basis. That is, from an administrative perspective, it would be less costly to adopt a system comprising fiscal settings that are consistently applied across resource projects.

There is the further issue that the risks inherent in exploration activity, particularly in frontier areas, are significantly higher than in the development and production stages of resource projects. Hence, there is an economic argument in support of setting a higher risk premium at the exploration stage (most notably, for higher risk exploration activity).

- ***no risk premium allowance***

A fundamental insight into the setting of the threshold rate in a resource rent tax was provided by Fane and Smith (1986). They argue that the threshold rate should be set equal to the risk free interest rate (the long term government bond rate) since, with full loss offset, the accumulated expenditures represent a certain reduction in future resource rent tax liabilities.

Fane and Smith argue that the future value of the tax reduction, where expenditure is accumulated at the long term government bond rate, is the same as a reduction in the company holdings of long term government bonds. That is, an investor has the option of reducing current holdings of long term government bonds to finance expenditure, forgoing the annual interest rate that would otherwise have accrued to be compensated when the reduction in tax liabilities is triggered. Alternatively, if the company does not hold long term government bonds, the expenditure may be financed through the release of corporate debentures with interest rates typically only marginally higher than the long term government bond rate.

Consistent with Fane and Smith (1986), Hinchy, Fisher and Wallace (1989) argue that the resource rent tax may be modified to approximate a Brown tax if the threshold rate is set equal to the risk free interest rate and ensuring there is full loss offset (either by providing a cash rebate on failed projects or allowing the sale of losses to other companies).

It may appear to be difficult to reconcile the differing views on the setting of the threshold rate and, in particular, the inclusion of a risk premium in the fiscal settings of a resource rent tax. It may be useful to note that, under the Brown tax, the government effectively acts as a silent partner in all resource projects, with cash rebates provided in years of losses and tax revenue collected in years of profit.

A resource rent tax where there is no (or a low) risk premium allowance is consistent with government acting as a silent partner that has ownership of the mineral resource but does not contribute in the initial stages to the financing of the project. It may then be assumed, consistent with the Fane and Smith (1986) argument, that the government's share of the financing is provided through company savings (held in long term government bonds) or through debt (incorporating a relatively low risk premium). The resource rent tax is not triggered until essentially the government has repaid its share of the project costs, accumulated at the threshold rate, to the private investor (the active partner). With full loss offset, the private investor receives the value of the government's implicit share in the project costs with certainty.

With less than full loss offset where not all relevant expenditures are deductible for resource rent tax assessment purposes, private investors may be compensated by introducing a risk premium in the fiscal settings and/or reducing the tax rate.

tax rate

There are a number of issues relating to the setting of the tax rate in either the Brown tax or the resource rent tax. A useful discussion of these issues is provided in Hinchy, Fisher and Wallace (1989). Most importantly, the tax rate needs to be sufficiently below 100 per cent to ensure that it does not seriously weaken efficiency incentives in the private sector.

Given these economic incentive issues, Garnaut and Clunies Ross (1979) discuss the possibility of jointly setting threshold and tax rates to increase the government's share of the economic rent while minimising distortions to investment. It should be noted, however, that this analysis was based on a project based system whereby the costs associated with failed projects are not taken into account in any assessment of resource rent tax liabilities.

Fane and Smith (1986) argue that the difficulties in making any actual tax proposal approximate the theoretical concept of a pure rent tax provide a justification for choosing a fairly low rate of rent tax. This pure rent tax has been referred to previously as a neutral tax – a graphical representation of a neutral tax is presented in the next section since it is a useful benchmark against which to assess some important features of other resource taxation policy options.

More generally, any tradeoff between government revenue and the efficiency of the tax system would involve a lower threshold rate to compensate the government for the lower tax rate required to maintain economic efficiencies in management and investment.

It is interesting to consider the implications of alternative tax rates under the interpretation that resource projects are essentially a joint venture between private investors and the government where the latter is the silent partner. The government owns the mineral resources and chooses the fiscal settings, presumably in consultation with industry. If the hypothetical choice of government is a Brown tax with a tax rate of 100 per cent, this implies that the private sector acts as a contractor that receives full payment for any initial exploration and investment costs, with the government collecting the net cash flow when it is positive.

As indicated earlier, the tax rate in the petroleum resource rent tax arrangements in Australia is 40 per cent. This rate provides private investors with significant incentives to pursue profit opportunities in the industry, while allowing the government to collect a reasonable share of the resource rents (although it should be noted that the system is somewhat more complex because of the lack of full loss offset).

output based royalties

The two main output based royalties are:

- *ad valorem royalty* – levied as a constant percentage of the value of output; and
- *specific royalty* – levied as a constant dollar amount on each physical unit of output.

The administrative and compliance costs of a resource taxation system increase with the amount of information required for its implementation. There are two issues. First, information on project profitability is required for all resource taxation options to determine appropriate fiscal settings and assess the need, if any, for change to these settings over time. Second, in terms of the application of resource taxation arrangements, output based royalties require less information than profit based royalties – the ad valorem royalty generally does not require cost data and the specific royalty does not require price or cost data.

Project profitability may vary widely between resource industries and within a resource industry. A consistent ad valorem royalty rate may be set for resource industries with similar revenue and cost profiles. However, separate specific royalty rates need to be set for each resource since this royalty rate is based on physical output.

Output based royalties are regressive since the resource tax burden is greater for lower profit projects. Under output based royalties, all projects within a particular category are subject to the same ad valorem or specific royalty rate – note that these output based royalty rates are equivalent if price is constant (ignoring any price differences that reflect resource quality differences) and the royalty rates are calibrated to collect the same amount per unit of output. In these circumstances, the royalty revenue collected, per unit of output, will be constant across all projects in the same category under each output based royalty option. However, project profitability may vary substantially between projects reflecting different cost structures (that is, the quality of the ore deposit or fossil fuel field may vary widely). In practice, since mineral resource prices change over time, the resource taxation revenue collected under an ad valorem royalty will differ from that collected under a specific royalty (unless fiscal settings are adjusted on an annual basis).

In setting the royalty rates, it is useful to have information about aggregate resource rent, indicating potential resource taxation revenue, as well as information on the distribution of resource rent across projects, indicating the extent to which high profit projects may be undertaxed and low profit projects may be overtaxed. In particular, policy makers need to make a subjective judgment about collecting a reasonable share of the industry's resource rent but managing the negative impact on the profitability of lower profit projects (particularly marginal projects that may become uneconomic under an output based royalty).

To fully identify the efficiency implications of output based royalties, it is also important to consider two mechanisms by which output based royalties influence the risk assessments of project profitability. First, output based royalties apply to projects in all years in which production is positive regardless of whether net cash flow is positive or negative. As a consequence, the risk premium is likely to be increased since royalty payments are still incurred under worse than expected market outcomes when net cash flow is negative – that is, the risk exposure of private investors for any given resource project during the production stage is increased under output based royalties (this is discussed further in the next chapter).

Second, sovereign risk may be higher under output based royalties than under profit based royalties. Sovereign risk is the risk of future change in the policy environment, with the main focus of concern being on any policy change that reduces project profitability. Mining activity is inherently dynamic with an ongoing process of mineral resource discovery, development and extraction, including an important role for technology adoption at all stages of the mining process. The geological and economic environment in the mining sector is therefore likely to change over time – the mining sector is also characterised by significant cyclical or medium term fluctuations.

Profit based arrangements are responsive to significant changes in project profitability, while fiscal settings in output based royalties are responsive only to changes in the value of production (ad valorem royalty) or production (specific royalty). Under output based royalties, private investors would need to assess the implications of any potential changes to the royalty rates under the same system as well as any potential change to a more efficient profit based royalty system. The general trend in economic policy formulation in Australia in recent decades has been toward achieving more efficient outcomes.

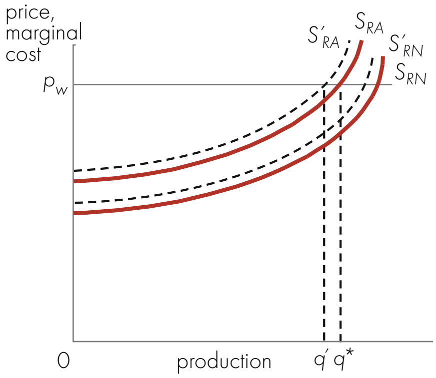
graphical presentation of the industry impacts of key resource taxation options

The economic implications of selected profit based royalties and output based royalties were examined in the previous section. To highlight the main aspects of this discussion, the industry impacts of these resource taxation arrangements are illustrated in this section using the simplified supply–demand framework presented earlier in figure B.

administrative costs

For simplicity, first consider the implications of increased administrative costs incurred by private investors to comply with resource tax obligations without identifying any particular resource tax. Higher administrative costs associated with this generic resource tax increase the long run marginal costs of industry supply – this is illustrated is figure C.

fig C **illustrative impact of increased administrative costs on long run industry supply** ignoring other implications of resource tax



For risk neutral investors, increased administrative costs may be represented as an upward shift in the expected long run marginal cost curve from S_{RN} to S'_{RN}. If the risk premium required by risk averse private investors is unchanged, the increase in administrative costs results in a corresponding increase in the long run industry supply curve from S_{RA} to S'_{RA}. Reflecting the higher cost structure of industry, equilibrium output falls from q* to q′.

The industry impacts will vary according to the resource taxation option that is adopted. In general, the information requirements of output based royalties are less than those for profit based royalties. Hence, the administrative costs are lower for output based royalties than for profit based royalties – that is, the upward shift in the long run industry supply curve will be relatively greater for profit based royalties than for output based royalties.

efficiency implications

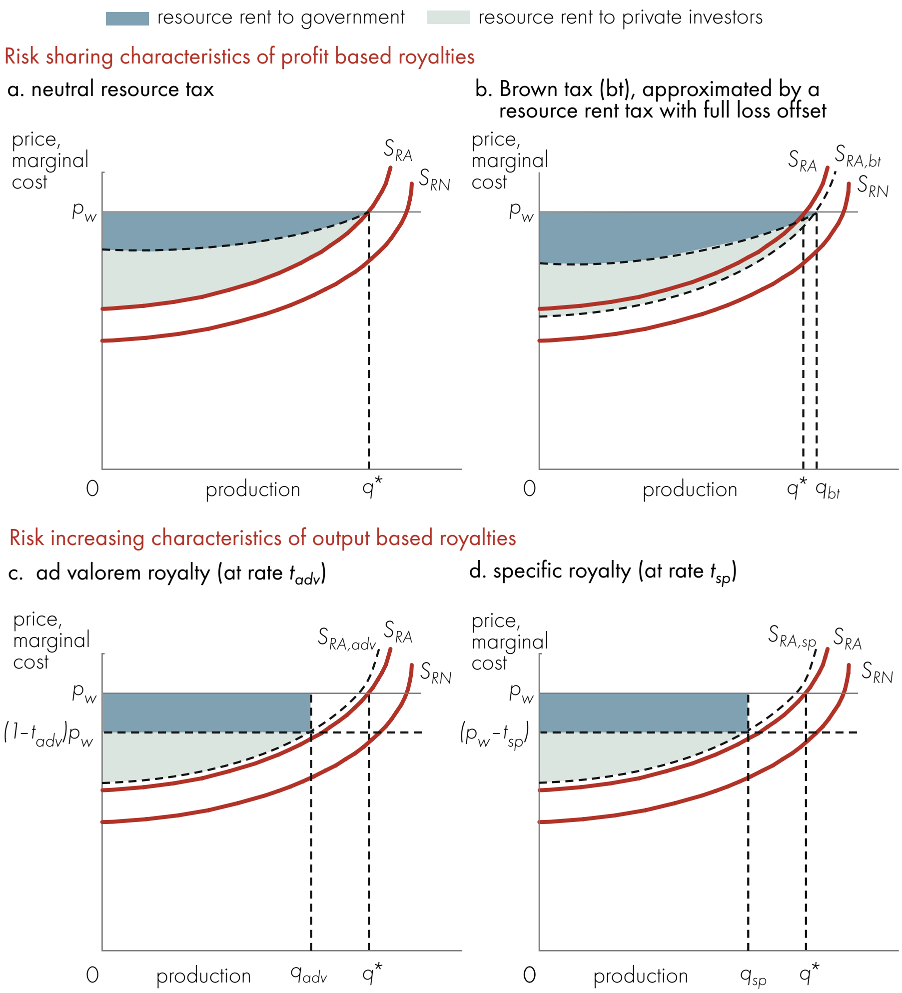
Now, consider the industry impacts of key resource taxation options ignoring administrative costs. Selected resource taxation options are illustrated in figure D.

profit based royalties

A ***neutral profit based royalty,*** represented in panel a of figure D, does not result in any change to private investment and production decisions – that is, equilibrium output is unchanged at q^*. As discussed previously in this chapter, a resource tax is neutral if the ranking of projects according to assessed profitability is unchanged and there is no change to the projects that are assessed to be profitable (or unprofitable) before and after the resource tax is implemented.

fig D **illustrative industry impacts of key resource tax options**

ignoring administrative costs



Under a neutral profit based royalty, the government collects a constant percentage of the resource rent. In practice, it would probably not be possible for a government to identify and implement a neutral profit based royalty. However, it is useful to include this option to highlight the economic implications of alternative resource taxation options.

The industry outcome under a ***Brown tax*** where government essentially acts as a silent partner in resource projects is illustrated in panel b of figure D. Under a Brown tax, the government provides the private investor with a cash rebate in years in which the net cash flow is negative – the cash rebate is equal to the tax rate, t_{bt}, multiplied by the loss. The government collects tax revenue from the private investor in years of positive net cash flow – the tax revenue is equal to the tax rate, t_{bt}, multiplied by the profit. In this 'joint venture', the implicit share of the government is equal to the tax rate.

An important aspect of the Brown tax is that it reduces the losses incurred by private investors if resource projects fail owing to unexpected adverse outcomes in the geological, economic and/or broader policy environment. That is, the risk exposure of private investors to losses is reduced under the Brown tax. By sharing the risks of resource projects, the risk premium required by private investors is reduced – this is represented as a downward shift in the long run industry supply curve from S_{RA} to $S_{RA,bt}$ in panel *b*.

A lower risk premium may result in some submarginal projects being reassessed as profitable and, as a consequence, equilibrium industry output may increase from q^* to q_{bt}. That is, with the risk sharing characteristics of the Brown tax, this resource tax may have a positive distortion on industry output.

The Brown tax may be approximated by a ***resource rent tax with full loss offset*** – whereby the losses incurred by private investors associated with failed projects are reduced with certainty by the tax rate – and where the threshold rate is set at the risk free interest rate since the resource rent tax obligations will be reduced by accumulated costs with certainty.

The mechanisms by which full loss offset may be achieved in a resource rent tax were outlined in the previous section. Without cash rebates, these mechanisms include companywide deductibility of losses on failed projects and allowing new companies without resource rent tax obligations to transfer losses to companies with resource rent tax obligations.

The government may prefer not to share in all of the risks of resource projects. Under a ***resource rent tax with exploration loss offset***, only exploration costs are deductible against resource rent tax obligations within the same company or may be sold by new companies for failed exploration projects (note that this latter feature is not part of the petroleum resource rent tax), but private investors incur the risks of failed projects in the development and production stages of the activity.

There are two effects that act in opposite directions. First, from an industry perspective, the resource rent is overestimated since not all the costs are incorporated in the resource rent tax calculations (that is, the expected long run marginal cost curve is lower in the calculations). Second, since there is partial risk sharing between the government and the private investor, the risk premium is likely to be reduced although not to the extent indicated in panel b of figure D. The government has the option of reducing the tax rate or introducing a risk premium in the threshold rate and/or the accelerated rate of deduction to compensate for the lack of full loss offset.

A ***resource rent tax applied only to successful projects*** is consistent with the original approach suggested by Garnaut and Clunies Ross (1975). Under this arrangement, the resource rent tax is triggered only on successful projects when private investors have achieved the threshold rate of return on exploration and capital expenditure within the corresponding lease area. It may be noted, however, that there is still some limited risk sharing between the government and private investors under this arrangement since the resource rent tax is not paid under adverse outcomes in the geological, economic and/or policy environment. The two effects noted above for the resource rent tax with exploration loss offset apply in this case, although the underestimation of industry costs for resource rent tax assessment purposes is greater and the benefits in terms of a lower risk premium are diminished. As in the previous case, the government has the option of reducing the tax rate further or increasing the risk premium in the threshold rate and/or the accelerated rate of deduction to compensate for the lack of full loss offset.

output based royalties

One of the most important characteristics of profit based royalties is that no tax is collected by government in years in which losses are made – the extent to which the government shares in the risks of failed projects varies according to the design of the resource rent tax system.

Unlike profit based royalties, output based royalties are triggered when production is positive. The industry outcomes under the ad valorem and specific royalties are illustrated in panels c and d, respectively, in figure D. Under the ***ad valorem royalty***, the government collects a constant percentage of the value of production (at a royalty rate of t_{adv} in panel c). Under the ***specific royalty***, the government collects a constant dollar amount per unit of output (at a royalty rate of t_{sp} in panel d).

In each case, the price received by private investors is reduced by the corresponding royalty rate: to $(1-t_{adv})p_w$ under an ad valorem royalty and to p_w-t_{sp} under a specific royalty. In figure D, for illustrative purposes, the royalty rates in the two output based royalty options are calibrated such that the after tax price received by private investors is the same under each system (that is, $(1-t_{adv})p_w= p_w-t_{sp}$ which implies $t_{sp}=t_{adv}\, p_w$).

An important feature of output based royalties is that, because the royalty applies in all years in which production is positive, the losses incurred under adverse outcomes for the geological, economic and/or broader policy environment will be larger than would otherwise be the case owing to the royalty obligations. (On a related point, private investors may be more likely to place mine sites on care and maintenance under output based royalties than under profit based royalties.) Since output based royalties increase the risk exposure of private investors, it is likely that private investors will increase the risk premium required to invest in resource projects. Sovereign risk may be argued to be higher under output based royalties which provides a further argument for suggesting the risk premium may increase under these resource taxation options.

A higher risk premium is represented as an upward shift in the long run industry supply curve from S_{RA} to $S_{RA,adv}$ (panel c) and $S_{RA,sp}$ (panel d) under the ad valorem and specific royalties, respectively. Industry output is reduced in each case from q^* to q_{adv} and q_{sp}, respectively. That is, output based royalties result in an unambiguous negative distortion to industry output which is amplified to the extent that the risk exposure of private investors is increased (and, hence, the risk premium in undertaking resource projects is increased).

It is apparent from figure D that the royalty revenue collected by government may vary significantly as a share of excess profit or resource rent between different projects. In setting the royalty rates in output based systems, there is a tradeoff between collecting royalty revenue and the negative impact on marginal projects.

To justify the ongoing reliance on output based royalty arrangements, the various jurisdictions in Australia need to assess whether the economic benefits of these arrangements in the form of lower administrative costs are expected to outweigh the economic costs in the form of efficiency losses and/or forgone royalty payments. In the next chapter, the impacts of resource taxation options on the profitability of hypothetical resource projects are simulated to provide further information that may be used as an input to the policy process.

4

project simulations — impact of key resource taxation policy options on government tax take and project profitability

The economic implications of key profit based and output based royalties were examined in the previous chapter using a supply-demand framework to highlight industry outcomes. In this chapter, a range of hypothetical resource development projects are identified and the impact of a number of resource taxation policy options on project profitability is quantified. The project simulations are based on an economic framework for the profitability assessments of risky projects by private investors. This economic framework is presented first, and simulation results for the hypothetical projects are provided in the absence of risk and then under price risk. A summary of the main simulation results is provided in chapter 5 for readers who wish to avoid the details of the simulation analysis.

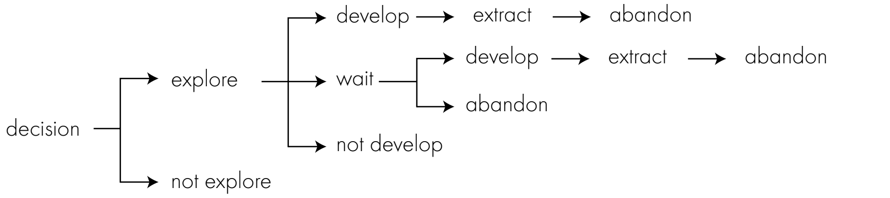
economic framework for decision making under risk

risky investment decisions in mining

As indicated earlier, mining is inherently a risky activity that involves the ongoing process of the discovery, development and (economic) depletion of ore deposits and fossil fuel fields. A simplified decision tree for potential mining activity in a lease area is presented in figure E.

At each stage of the decision tree – exploration (broadly defined to include area selection, detailed exploration and evaluation of discoveries), development, production and related processing, and mine site rehabilitation and abandonment – there are geological, economic and policy risks. These risks tend to be reduced as the investor gains information and proceeds through each stage for any given project.

fig E **simplified decision tree for risky resource projects**



Investment decisions must be made by private mining companies in both the exploration and development stages of a resource project:

- *exploration expenditure* is an investment in knowledge about the location, size and quality of ore deposits (or fossil fuel fields)
- *development expenditure* is an investment in the physical infrastructure required for extraction and basic processing at the mine site.

In practice, followup exploration activity may occur during the production stage of a project to prove up further resources to extend the life of the mining operation, and there may be additional investment in plant and equipment, for example, to adopt new technologies at the mine site. However, it is useful to focus on the key stages in mining to highlight the major investment decisions that are required to be made by mining companies. Key stages in mining are discussed further in, for example, Williams and Huleatt (1996) and Hogan et al. (2002).

profitability assessments for risky projects – certainty equivalent approach

The focus in this study is on the implications of alternative resource taxation options for the development decisions of private investors, although it may be noted that the economic framework presented below is also relevant to exploration decisions.

The assessment of the profitability of a prospective resource project following successful exploration activity depends on the expected geological, economic and policy setting over the life of the resource project, risks in the outlook and the attitude (or preferences) of private investors to incurring those risks. The main decision criteria used in the profitability assessments for risky resource projects are summarised in table 6.

Consider first a risk free investment. In the absence of risk, private investors are assumed to summarise the profitability of a potential resource project by calculating the net present value. The **net present value** of a risk free project is the sum of the annual net cash flow over the duration of the project discounted at the risk free interest rate (assumed to be the long term government bond rate or LTBR).

It is useful to note that the net present value, *NPV*, in year 0 prices may be presented simply in algebraic terms as:

(1) $$NPV = \sum_s V_s / (1+i_{rf})^s$$

where V_s is the net cash flow of the project in year s, i_{rf} is the risk free interest rate and $\sum_s$ is the summation sign over all years in the project (with $s = 0,1,2, \ldots T$ where T is the final year in the project life).

Projects may be ranked according to the net present value since it is a measure of the return to the investment. A project with a net present value that is greater or equal to zero is assessed to be profitable since it indicates that the investment will achieve a return that is greater or equal to the risk free interest rate (table 6).

In the presence of risk, private investors are assumed to summarise the profitability of a potential resource project by calculating the expected net present value if they are risk neutral, or the certainty equivalent value if they are either risk averse or risk preferring:

- *risk neutral investors* are indifferent to the risk that an outcome may be either worse or better than expected
- *risk averse investors* are relatively more concerned about the risk of unexpected losses than the risk of unexpected gains
- *risk preferring investors* (often referred to as gamblers) value the risk of unexpected gains more highly than the risk of unexpected losses.

In each case, the private investor is assumed to be able to identify a range of possible outcomes reflecting the significant sources of risk and assign (objective or subjective) probabilities to each of these outcomes. For example, price is usually considered to be a major source of risk in resource development projects and hence project profitability may be assessed under a range of possible price outcomes (price risk is included in the project simulations later in this chapter).

table 6 **decision criteria for profitability assessments of resource projects**

risk/attitude toward risk	**profitability measure**	**profitability assessment**		
		uneconomic	**marginal**	**economic**
risk free project	net present value (NPV)	< 0	= 0	> 0
risky project				
– risk neutral investor	expected net present value (ENPV)	< 0	= 0	> 0
– risk averse investor	certainty equivalent value (CEV)	< 0	= 0	> 0

The ***expected net present value*** is the probability weighted sum of the net present value of each possible outcome. The expected net present value, *ENPV*, in year 0 prices may be presented simply in algebraic terms as:

$$ENPV = \sum_k Pr_k \, NPV_k \qquad (2)$$

where Pr_k is the probability that a possible outcome *k* may occur (noting that each probability has a value in the range from 0 to 1, and probabilities must sum to 1; that is, $0<Pr_k<1$ and $\sum_k Pr_k=1$), NPV_k is the net present value of the project in possible outcome *k* and $\sum_k$ is the summation sign over possible outcomes (with $k = 0,1,2, \ldots K$ where *K* is the total number of possible outcomes).

For risk neutral private investors, projects may be ranked according to the expected net present value since it is now the relevant measure of the return to the investment. A project with an expected net present value that is greater or equal to zero is assessed to be profitable since it indicates that the investment is expected to achieve a return that is greater or equal to the risk free interest rate (table 6).

The ***certainty equivalent value*** of a project is the amount where the investor would be indifferent to investing in the risky project or accepting a risk free investment with a certain return. For risk averse private investors, the certainty equivalent value is the expected net present value less a risk premium that provides adequate compensation for the risks associated with the project.

In simple algebraic terms, the certainty equivalent value, *CEV*, of a project for a risk averse investor may be expressed as:

$$CEV = ENPV - RP \qquad (3)$$

where *ENPV* is the expected net present value, as defined previously, and *RP* is the risk premium.

For risk preferring private investors, the certainty equivalent value is the expected net present value plus a risk discount that indicates the additional value placed on the opportunity to achieve a higher return on the investment than would be expected.

Following the approach usually adopted in economic studies based on observations of actual market behaviour, private investors are assumed to be risk averse in profitability assessments of risky investment projects – related to this discussion, as noted in the previous chapter, governments are assumed to be risk neutral in economic assessments of alternative policy options. Thus, private investors are assumed to rank projects according to the certainty equivalent value and only consider investing in projects with a non-negative risk adjusted value (see table 6). Similarly, governments are assumed to rank policy options according to the expected net economic benefits (see chapter 3 for a further discussion of this issue, particularly in the context of the current study).

In the economics literature, expected utility theory is a commonly used approach to estimate the certainty equivalent value of a risky project. Applications of expected utility theory in the resource taxation literature include, for example, Emerson and Garnaut (1984), and Campbell and Lindner (1987). According to expected utility theory, the investor assesses the utility of the risky options and prefers the project with the highest expected utility.

As Hinchy, Fisher and Wallace (1989) note, the mean–variance framework is a simple approach that is also often used in practice. In this approach, projects are ranked on the basis of the mean and variance of the probability distributions. The variance is a measure of the risk of the project. A probability distribution is strictly preferred to an alternative if it has a larger mean and smaller variance. In other cases, the investor needs to trade off the mean and variance by using some other approach.

The mean and variance refer to the first and second moments of the probability distribution of the net present value. Other theories refer to the role of skewness (the third moment of the probability distribution) in ranking projects. Skewness provides a measure of the lack of symmetry or the extent to which a probability distribution is positively or negatively skewed. The third moment will be positive if the distribution is positively skewed (as is likely to be the case in mineral or petroleum exploration). Kurtosis, given by the fourth moment, provides a measure of the extent to which a distribution is peaked or flat – this moment is not often used in economic studies.

In practice, investors use a range of criteria to assess the viability of projects including for example the internal rate of return, the net present value based on a risk adjusted discount rate and the payback period.

- *internal rate of return* – the discount rate that would result in a zero net present value, although it should be noted that the internal rate of return may not be well defined in some circumstances (see, for example, Brealey and Myers 1991 for a discussion of this issue) – a project is assessed to be profitable if the internal rate of return exceeds some specified minimum rate of return or hurdle rate

- *net present value based on a risk adjusted discount rate* – if the discount rate is the minimum rate of return or hurdle rate, a project is assessed to be profitable by a risk averse private investor if the corresponding net present value is non-negative
- *payback period* – the number of years before the investment expenditures are recouped.

In this study, the certainty equivalent approach, whereby the relevant discount rate in calculating the net present value is the risk free interest rate, represents a consistent economic framework that may be used to highlight the efficiency implications of profit based royalties, particularly under conditions of risk aversion.

An algebraic representation of the impact of resource taxation options on the net cash flow of a resource project is presented in box 1.

box 1: an algebraic representation of key resource taxation options

In this box, an algebraic representation of profit based royalties and output based royalties is presented using a simple example of a resource project.

net cash flow of a resource project

Assume an ore deposit (or fossil fuel field) has been discovered in the exploration stage of a project. Ignoring resource taxation options, the annual net cash flow of the resource project may be presented in simple algebraic terms as:

(1) $$V_s = p_s q_s - c_s$$

where the subscript s refers to the year (s = 0,1,2,...,*T*), V_s is net cash flow, p_s is price, q_s is production and c_s is the cost of the resource project which may be disaggregated as follows:

(2) $$c_s = c_{exp,s} + c_{dev,s} + c_{op,s}$$

where $c_{exp,s}$, $c_{dev,s}$ and $c_{op,s}$ are the annual exploration, development and operating costs, respectively, that are associated with the exploration, development and production (including abandonment) stages of the resource project.

continued...

box 1 **an algebraic representation of key resource taxation options** *continued*

Following the introduction of resource taxation, it is important to distinguish between the net cash flow of the project that accrues to the private investor and resource taxation revenue collected by the government. After resource taxation, the value of the project may be presented as:

(3) $$V_{js} = V_{inv,js} + V_{gov,js}$$

where the subscript *j* refers to the resource taxation option (*j*=bt for the Brown tax, rrt for the resource rent tax, *adv* for the ad valorem royalty and *sp* for the specific royalty), V_{js} is the value or net cash flow of the project in year *s*, $V_{inv,js}$ is the project's net cash flow that accrues to the private investor and $V_{gov,js}$ is the resource taxation revenue collected by the government.

profit based royalties

Brown tax

The Brown tax is levied as a constant percentage, t_{bt}, of annual net cash flow. The Brown tax is included here to provide a benchmark against which to assess the key resource taxation options – it should be emphasised that, in this report, the Brown tax is not considered to be a feasible policy option for implementation since it involves cash rebates to private investors in years of negative net cash flow. Under the Brown tax, the return to the private investor in year *s*, $V_{inv,bt,s}$, is:

(4) $$V_{inv,bt,s} = (1 - t_{bt})(p_s q_s - c_s)$$

and annual tax revenue collected by the government, $V_{gov,bt,s}$, is:

(5) $$V_{gov,bt,s} = t_{bt}(p_s q_s - c_s) = t_{bt} V_s$$

where

(6a) $$V_{gov,bt,s} < 0 \qquad \text{if } V_s < 0$$

(6b) $$\geq 0 \qquad \text{if } V_s \geq 0$$

That is, a cash rebate is provided to private investors in years in which net cash flow is negative.

resource rent tax

Under a resource rent tax, cash rebates are avoided by allowing all losses to be accumulated at a threshold rate and offset against future profits. The resource rent tax is levied as a constant percentage, t_{rrt}, of annual net cash flow including accumulated losses. For simplicity, under the resource rent tax, the return to the private investor in

box 1 **an algebraic representation of key resource taxation options** *continued*

year *s*, $V_{inv,rrt,s}$, may be expressed as the difference between the before tax net cash flow and the tax revenue collected by the government, $V_{gov,rrt,s}$:

(7) $$V_{inv,rrt,s} = V_s - V_{gov,rrt,s}$$

and tax revenue is given by:

(8a) $$V_{gov,rrt,s} = 0 \quad \text{if } V_s \leq 0$$

(8b) $$= 0 \quad \text{if } V_s > 0 \text{ and } 0 < t_{rrt} V_s \leq V_{rrtd,s}$$

(8c) $$= t_{rrt} V_s - V_{rrtd,s} > 0 \quad \text{if } V_s > 0 \text{ and } 0 < V_{rrtd,s} < t_{rrt} V_s$$

(8d) $$= t_{rrt} V_s > 0 \quad \text{if } V_s > 0 \text{ and } V_{rrtd,s} = 0$$

where $V_{rrtd,s}$ is the value of the tax deduction for the accumulated losses. For simplicity, assume investment costs are incurred in year 0 and are given by c_0. The value of the tax deduction of the accumulated losses in year *s* is:

(9a) $$V_{rrtd,s} = t_{rrt} (1+i)^s (1+a) c_0 \quad \text{if } a > 0$$

(9b) $$= t_{rrt} (1+i)^s c_0 \quad \text{if } a = 0$$

where *i* is the threshold rate at which costs are accumulated and *a* is the accelerated rate of deduction. The threshold rate potentially has two components corresponding to the risk free interest rate, i_{rf}, and the risk premium in the threshold rate, i_{rp} (that is, $i=i_{rf} + i_{rp}$). With full loss offset (see the main text in chapter 3 for a discussion of this aspect of the resource rent tax), no risk premium is included in the value of the tax deduction (that is, $i=i_{rf}$ and $a=0$).

With less than full loss offset, governments may provide private investors with a risk premium through the threshold rate and/or the accelerated rate of deduction (that is, $i_{rp}>0$ and/or $a>0$).

output based royalties

ad valorem royalty

The ad valorem royalty is levied as a constant percentage, t_{adv}, of the value of production. Under the ad valorem royalty, the return to the private investor in year *s*, $V_{inv,adv,s,}$ is:

(10) $$V_{inv,adv,s} = (1 - t_{adv}) p_s q_s - c_s$$

and annual tax revenue collected by the government, $V_{gov,adv,s,}$ is:

(11) $$V_{gov,adv,s} = t_{adv} \, p_s q_s$$

where

(12a) $$V_{gov,adv,s} = 0 \quad \text{if } q_s = 0$$

box 1 **an algebraic representation of key resource taxation options** *continued*

(12b) > 0 if $q_s > 0$

That is, revenue is collected by the government under an ad valorem royalty in years in which production is positive.

specific royalty

The specific royalty is levied as a constant dollar amount, t_{sp}, on each physical unit of production. Under the specific royalty, the return to the private investor in year s, $V_{inv,sp,s}$ is:

(13) $$V_{inv,sp,s} = (p_s - t_{sp})\, q_s - c_s$$

and annual tax revenue collected by the government, $V_{gov,sp,s}$ is:

(14) $$V_{gov,sp,s} = t_{sp}\, q_s$$

where

(15a) $V_{gov,sp,s} = 0$ if $q_s = 0$

(15b) > 0 if $q_s > 0$

That is, as with the ad valorem royalty, revenue is collected by the government under a specific royalty in years in which production is positive.

impact of resource taxation options on hypothetical resource projects in the absence of risk

hypothetical resource projects – assumptions

In this chapter, a number of hypothetical resource projects are used to illustrate the impact of alternative resource taxation options on project profitability and government tax revenue. Five hypothetical resource projects are defined with two assumptions for capital costs, referred to as lower and higher capital costs. For simplicity, all projects are assumed to produce a single ore that is sold at the same market price, $1000 a tonne. The production and cost assumptions for these illustrative resource projects are presented in table 7. The projects vary widely in terms of size with the value of production assumed to range from $5 million for project 1 to $250 million for project 5.

Exploration costs are assumed to have been incurred in a single year (year 0) and are included to illustrate the different treatment of exploration costs between profit based royalties and output based royalties. Capital costs are also assumed to be incurred in a single year (year 1). The cost structure reflects the presence of economies of scale, whereby average operating costs are lower for larger projects. Production and operating costs are assumed to be constant during the production phase of each project. The mine life is assumed to be twenty years for project 5 and ten years for the other projects. For simplicity, abandonment costs are not explicitly included in the cost structure.

The assumptions for other relevant variables and the policy settings in the resource taxation options are given in table 8. The profitability assessment of each project is based on the net present value where the project's net cash flow is discounted at the risk free interest rate, assumed to be 5 per cent.

The tax rate in the Brown tax, included as a benchmark royalty, and the resource rent tax is assumed to be 40 per cent, consistent with the current setting in Australia's petroleum resource rent tax system. Two options are considered for the threshold rate in the resource rent tax: 5 per cent (that is, no risk premium in the threshold rate) and 10 per cent (that is, a risk premium of 5 per cent in the threshold rate). This latter assumption for the threshold rate is consistent with the approach in the petroleum resource rent tax where general project expenditures are accumulated at the risk free interest rate plus 5 per cent. However, in the project simulations, no distinction is made between exploration expenditure and

table 7 **production and cost assumptions for hypothetical resource projects**

		project 1	project 2	project 3	project 4	project 5
value of production	**$m**	**5**	**25**	**50**	**100**	**250**
price	$/t	1000	1000	1000	1000	1000
resource size	kt	50	250	500	1000	5000
mine life	no. years	10	10	10	10	20
annual production	kt	5	25	50	100	250
costs						
exploration costs	$m	2	5	10	15	30
capital costs **a**						
– lower capital costs	$m	10	50	100	200	500
– higher capital costs	$m	12.5	62.5	125	250	625
operating costs	$m	2.5	12.5	20	30	50
average operating costs	$/t	500	500	400	300	200

a Hypothetical resource projects are defined under two alternative assumptions for capital costs. The main simulation results are based on the assumption of lower capital costs.

table 8 **assumptions for other variables and policy settings**

		assumption
risk free interest rate	%	5
inflation rate	%	3
Brown tax		
tax rate	%	40
resource rent tax		
tax rate	%	40
threshold rate		
– option 1 no risk premium	%	5
– option 2 with risk premium	%	10
accelerated rate of deduction	%	0
ad valorem royalty		
royalty rate		
– option 1	%	10
– option 2	%	5
specific royalty		
royalty rate		
– option 1	$/t	100
– option 2	$/t	50

development expenditure, and only project expenditure is included (issues relating to full loss offset including the losses associated with failed projects are not addressed directly in this chapter). For simplicity, the accelerated rate of deduction is assumed to be zero. It would be a relatively straightforward exercise to extend the simulations to examine the implications of alternative policy settings.

To illustrate the impact of different policy settings, two options are considered for the royalty rate in each of the output based royalties. The royalty rate in the ad valorem royalty is assumed to be either 10 per cent or 5 per cent. Given a price of $1000 a tonne, the corresponding royalty rates in the specific royalty are $100 a tonne and $50 a tonne, respectively. That is, the ad valorem and specific royalty rates are calibrated such that the government tax take is the same under each royalty provided the resource price remains constant at $1000 a tonne – the implications of price risk for the profitability assessments of resource projects under these policy options may then be examined in the next section.

net cash flow of hypothetical resource projects

In this subsection, the net cash flow of the hypothetical resource projects both before and after resource taxation is presented in detail under the assumption of lower capital costs. The profitability measures (net present value and internal rate of return) of each project under assumptions of lower and higher capital costs are presented in the next subsection.

The net cash flow for each project before resource taxation is presented in table 9, and the net cash flow of each project under profit based royalties and output based royalties is presented in tables 10 and 11 respectively. In each table, the notation for the relevant variable is included to facilitate any comparison with the algebraic representation of net cash flow given in box 1.

For each project, net cash flow before resource taxation is negative in year 0 (exploration expenditure) and year 1 (capital expenditure), and positive during the production stage (years 2–11 for projects 1–4, and years 2–21 for project 5). Annual net cash flow or profit in the production stage ranges from $2.5 million for project 1 to $200 million for project 5 (table 9).

The risk sharing characteristics of profit based royalties are indicated in table 10. Under the Brown tax, the government provides a cash rebate to the private investor in years 0 and 1, reducing the exploration and capital costs of the private investor by 40 per cent (equivalent to the tax rate). During the production stage, the government collects 40 per cent of the annual net cash flow.

Under the resource rent tax, the losses incurred by the private investor are accumulated at a threshold rate of either 5 per cent (no risk premium) or 10 per cent (5 per cent risk premium), and offset against future profits. The number of years of positive production and net cash flow during which the government does not collect tax revenue varies between the policy settings (the assumed risk premium in the threshold rate) as well as between projects.

For the resource rent tax with no risk premium (5 per cent risk premium) in the threshold rate, the government does not collect tax revenue in the first five years of production (seven) for project 1, five years (six) for project 2, four years (four) for project 3, three years (three) for project 4 and two years (three) for project 5 (note that production commences in year 2 in each project). That is, a higher threshold rate increases the accumulated value of losses and resource rent tax tends to be triggered later. In addition, the number of years in which the government does not collect tax revenue tends to be lower for higher profit projects – in the hypothetical resource projects, this result occurs because of the presence of economies of scale (see table 7).

By contrast, under output based royalties, government tax revenue is collected throughout the production stage (table 11). Under the ad valorem royalty, the government collects either 10 per cent or 5 per cent of the value of production (or revenue). For each project, the net cash flow under both ad valorem royalty options remains positive and constant during the production stage. Compared with net cash flow after tax under the resource rent tax options, net cash flow after tax under the ad valorem and specific royalty options tends to be lower in the early years of the production stage (that is, in years when resource rent tax collections are zero or low) and tends to be higher in subsequent years (when all accumulated losses in the resource rent tax options have been deducted).

table 9 **net cash flow for hypothetical resource projects before resource taxation** lower capital costs

year	revenue			costs				net cash flow
	price	production	revenue	exploration	development	operating	total	
	p	q	pq	c_{exp}	c_{dev}	c_{op}	c	V
	$/t	kt	$m	$m	$m	$m	$m	$m
project 1								
0				2			2.0	-2.0
1					10		10.0	-10.0
2	1 000	5	5			2.5	2.5	2.5
3	1 000	5	5			2.5	2.5	2.5
4	1 000	5	5			2.5	2.5	2.5
5	1 000	5	5			2.5	2.5	2.5
6	1 000	5	5			2.5	2.5	2.5
7	1 000	5	5			2.5	2.5	2.5
8	1 000	5	5			2.5	2.5	2.5
9	1 000	5	5			2.5	2.5	2.5
10	1 000	5	5			2.5	2.5	2.5
11	1 000	5	5			2.5	2.5	2.5
project 2								
0				5			5.0	-5.0
1					50		50.0	-50.0
2	1 000	25	25			12.5	12.5	12.5
3	1 000	25	25			12.5	12.5	12.5
4	1 000	25	25			12.5	12.5	12.5
5	1 000	25	25			12.5	12.5	12.5
6	1 000	25	25			12.5	12.5	12.5
7	1 000	25	25			12.5	12.5	12.5
8	1 000	25	25			12.5	12.5	12.5
9	1 000	25	25			12.5	12.5	12.5
10	1 000	25	25			12.5	12.5	12.5
11	1 000	25	25			12.5	12.5	12.5
project 3								
0				10			10	-10
1					100		100	-100
2	1 000	50	50			20	20	30
3	1 000	50	50			20	20	30
4	1 000	50	50			20	20	30
5	1 000	50	50			20	20	30
6	1 000	50	50			20	20	30
7	1 000	50	50			20	20	30
8	1 000	50	50			20	20	30
9	1 000	50	50			20	20	30
10	1 000	50	50			20	20	30
11	1 000	50	50			20	20	30

continued...

table 9 **net cash flow for hypothetical resource projects before resource taxation** lower capital costs *continued*

year	revenue			costs				net cash flow
	price	production	revenue	exploration	development	operating	total	
	p	q	pq	c_{exp}	c_{dev}	c_{op}	c	V
	$/t	kt	$m	$m	$m	$m	$m	$m
project 4								
0				15			15	-15
1					200		200	-200
2	1 000	100	100			30	30	70
3	1 000	100	100			30	30	70
4	1 000	100	100			30	30	70
5	1 000	100	100			30	30	70
6	1 000	100	100			30	30	70
7	1 000	100	100			30	30	70
8	1 000	100	100			30	30	70
9	1 000	100	100			30	30	70
10	1 000	100	100			30	30	70
11	1 000	100	100			30	30	70
project 5								
0				30			30	-30
1					500		500	-500
2	1 000	250	250			50	50	200
3	1 000	250	250			50	50	200
4	1 000	250	250			50	50	200
5	1 000	250	250			50	50	200
6	1 000	250	250			50	50	200
7	1 000	250	250			50	50	200
8	1 000	250	250			50	50	200
9	1 000	250	250			50	50	200
10	1 000	250	250			50	50	200
11	1 000	250	250			50	50	200
12	1 000	250	250			50	50	200
13	1 000	250	250			50	50	200
14	1 000	250	250			50	50	200
15	1 000	250	250			50	50	200
16	1 000	250	250			50	50	200
17	1 000	250	250			50	50	200
18	1 000	250	250			50	50	200
19	1 000	250	250			50	50	200
20	1 000	250	250			50	50	200
21	1 000	250	250			50	50	200

table 10 **profit based royalties** – government tax revenue and net cash flow after tax for hypothetical resource projects lower capital costs

	Brown tax		resource rent tax: no risk premium			resource rent tax: 5% risk premium		
	tax revenue	net cash flow after tax	accumu-lated losses	tax revenue	net cash flow after tax	accumu-lated losses	tax revenue	net cash flow after tax
	V_{gov} $m	V_{inv} $m	$m	V_{gov} $m	V_{inv} $m	$m	V_{gov} $m	V_{inv} $m
project 1								
0	-0.8	-1.2	-2.0	0.0	-2.0	-2.0	0.0	-2.0
1	-4.0	-6.0	-12.1	0.0	-10.0	-12.2	0.0	-10.0
2	1.0	1.5	-10.2	0.0	2.5	-10.9	0.0	2.5
3	1.0	1.5	-8.2	0.0	2.5	-9.5	0.0	2.5
4	1.0	1.5	-6.1	0.0	2.5	-8.0	0.0	2.5
5	1.0	1.5	-3.9	0.0	2.5	-6.3	0.0	2.5
6	1.0	1.5	-1.6	0.0	2.5	-4.4	0.0	2.5
7	1.0	1.5	0.8	0.3	2.2	-2.3	0.0	2.5
8	1.0	1.5		1.0	1.5	-0.1	0.0	2.5
9	1.0	1.5		1.0	1.5	2.4	1.0	1.5
10	1.0	1.5		1.0	1.5		1.0	1.5
11	1.0	1.5		1.0	1.5		1.0	1.5
project 2								
0	-2	-3	-5	0	-5	-5	0	-5
1	-20	-30	-55	0	-50	-56	0	-50
2	5	7.5	-46	0	13	-49	0	13
3	5	7.5	-35	0	13	-41	0	13
4	5	7.5	-25	0	13	-32	0	13
5	5	7.5	-13	0	13	-23	0	13
6	5	7.5	-1	0	13	-13	0	13
7	5	7.5	11	4	8	-2	0	13
8	5	7.5		5	8	10	4	8
9	5	7.5		5	8		5	8
10	5	7.5		5	8		5	8
11	5	7.5		5	8		5	8
project 3								
0	-4	-6	-10	0	-10	-10	0	-10
1	-40	-60	-111	0	-100	-111	0	-100
2	12	18	-86	0	30	-92	0	30
3	12	18	-60	0	30	-71	0	30
4	12	18	-33	0	30	-48	0	30
5	12	18	-5	0	30	-23	0	30
6	12	18	25	10	20	4	2	28
7	12	18		12	18		12	18

continued...

table 10 **profit based royalties** – government tax revenue and net cash flow after tax for hypothetical resource projects lower capital costs *continued*

	Brown tax		resource rent tax: no risk premium			resource rent tax: 5% risk premium		
year	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m	accumu-lated losses $m	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m	accumu-lated losses $m	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m
project 3 *continued*								
8	12	18		12	18		12	18
9	12	18		12	18		12	18
10	12	18		12	18		12	18
11	12	18		12	18		12	18
project 4								
0	-6	-9	-15	0	-15	-15	0	-15
1	-80	-120	-216	0	-200	-217	0	-200
2	28	42	-157	0	70	-168	0	70
3	28	42	-94	0	70	-115	0	70
4	28	42	-29	0	70	-56	0	70
5	28	42	39	16	54	8	3	67
6	28	42		28	42		28	42
7	28	42		28	42		28	42
8	28	42		28	42		28	42
9	28	42		28	42		28	42
10	28	42		28	42		28	42
11	28	42		28	42		28	42
project 5								
0	-12	-18	-30	0	-30	-30	0	-30
1	-200	-300	-532	0	-500	-533	0	-500
2	80	120	-358	0	200	-386	0	200
3	80	120	-176	0	200	-225	0	200
4	80	120	15	6	194	-47	0	200
5	80	120		80	120	148	59	141
6	80	120		80	120		80	120
7	80	120		80	120		80	120
8	80	120		80	120		80	120
9	80	120		80	120		80	120
10	80	120		80	120		80	120
11	80	120		80	120		80	120
12	80	120		80	120		80	120
13	80	120		80	120		80	120
14	80	120		80	120		80	120
15	80	120		80	120		80	120

continued...

table 10 **profit based royalties** – government tax revenue and net cash flow after tax for hypothetical resource projects lower capital costs *continued*

	Brown tax		resource rent tax: no risk premium			resource rent tax: 5% risk premium		
year	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m	accumu-lated losses $m	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m	accumu-lated losses $m	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m
project 5 *continued*								
16	80	120		80	120		80	120
17	80	120		80	120		80	120
18	80	120		80	120		80	120
19	80	120		80	120		80	120
20	80	120		80	120		80	120
21	80	120		80	120		80	120

table 11 **output based royalties** – government tax revenue and net cash flow after tax for hypothetical resource projects lower capital costs

	ad valorem royalty: 10% royalty		ad valorem royalty: 5% royalty		specific royalty: $100/t royalty		specific royalty: $50/t royalty	
year	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m
project 1								
0	0.0	-2.0	0.0	-2.0	0.0	-2.0	0.0	-2.0
1	0.0	-10.0	0.0	-10.0	0.0	-10.0	0.0	-10.0
2	0.5	2.0	0.3	2.3	0.5	2.0	0.3	2.3
3	0.5	2.0	0.3	2.3	0.5	2.0	0.3	2.3
4	0.5	2.0	0.3	2.3	0.5	2.0	0.3	2.3
5	0.5	2.0	0.3	2.3	0.5	2.0	0.3	2.3
6	0.5	2.0	0.3	2.3	0.5	2.0	0.3	2.3
7	0.5	2.0	0.3	2.3	0.5	2.0	0.3	2.3
8	0.5	2.0	0.3	2.3	0.5	2.0	0.3	2.3
9	0.5	2.0	0.3	2.3	0.5	2.0	0.3	2.3
10	0.5	2.0	0.3	2.3	0.5	2.0	0.3	2.3
11	0.5	2.0	0.3	2.3	0.5	2.0	0.3	2.3

continued...

table 11 **output based royalties** – government tax revenue and net cash flow after tax for hypothetical resource projects lower capital costs *continued*

	ad valorem royalty				specific royalty			
	10% royalty		5% royalty		$100/t royalty		$50/t royalty	
year	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m	tax revenue V_{gov} $m	net cash flow after tax V_{inv} $m
project 2								
0	0	-5	0	-5	0	-5	0	-5
1	0	-50	0	-50	0	-50	0	-50
2	3	10	1	11	3	10	1	11
3	3	10	1	11	3	10	1	11
4	3	10	1	11	3	10	1	11
5	3	10	1	11	3	10	1	11
6	3	10	1	11	3	10	1	11
7	3	10	1	11	3	10	1	11
8	3	10	1	11	3	10	1	11
9	3	10	1	11	3	10	1	11
10	3	10	1	11	3	10	1	11
11	3	10	1	11	3	10	1	11
project 3								
0	0	-10	0	-10	0	-10	0	-10
1	0	-100	0	-100	0	-100	0	-100
2	5	25	3	28	5	25	3	28
3	5	25	3	28	5	25	3	28
4	5	25	3	28	5	25	3	28
5	5	25	3	28	5	25	3	28
6	5	25	3	28	5	25	3	28
7	5	25	3	28	5	25	3	28
8	5	25	3	28	5	25	3	28
9	5	25	3	28	5	25	3	28
10	5	25	3	28	5	25	3	28
11	5	25	3	28	5	25	3	28
project 4								
0	0	-15	0	-15	0	-15	0	-15
1	0	-200	0	-200	0	-200	0	-200
2	10	60	5	65	10	60	5	65
3	10	60	5	65	10	60	5	65
4	10	60	5	65	10	60	5	65
5	10	60	5	65	10	60	5	65
6	10	60	5	65	10	60	5	65

continued...

table 11 **output based royalties** – government tax revenue and net cash flow after tax for hypothetical resource projects lower capital costs *continued*

	ad valorem royalty				specific royalty			
	10% royalty		5% royalty		\$100/t royalty		\$50/t royalty	
year	tax revenue V_{gov} \$m	net cash flow after tax V_{inv} \$m	tax revenue V_{gov} \$m	net cash flow after tax V_{inv} \$m	tax revenue V_{gov} \$m	net cash flow after tax V_{inv} \$m	tax revenue V_{gov} \$m	net cash flow after tax V_{inv} \$m
project 4 *continued*								
7	10	60	5	65	10	60	5	65
8	10	60	5	65	10	60	5	65
9	10	60	5	65	10	60	5	65
10	10	60	5	65	10	60	5	65
11	10	60	5	65	10	60	5	65
7	10	60	5	65	10	60	5	65
8	10	60	5	65	10	60	5	65
9	10	60	5	65	10	60	5	65
10	10	60	5	65	10	60	5	65
11	10	60	5	65	10	60	5	65
project 5								
0	0	-30	0.0	-30.0	0	-30	0.0	-30.0
1	0	-500	0.0	-500.0	0	-500	0.0	-500.0
2	25	175	12.5	187.5	25	175	12.5	187.5
3	25	175	12.5	187.5	25	175	12.5	187.5
4	25	175	12.5	187.5	25	175	12.5	187.5
5	25	175	12.5	187.5	25	175	12.5	187.5
6	25	175	12.5	187.5	25	175	12.5	187.5
7	25	175	12.5	187.5	25	175	12.5	187.5
8	25	175	12.5	187.5	25	175	12.5	187.5
9	25	175	12.5	187.5	25	175	12.5	187.5
10	25	175	12.5	187.5	25	175	12.5	187.5
11	25	175	12.5	187.5	25	175	12.5	187.5
12	25	175	12.5	187.5	25	175	12.5	187.5
13	25	175	12.5	187.5	25	175	12.5	187.5
14	25	175	12.5	187.5	25	175	12.5	187.5
15	25	175	12.5	187.5	25	175	12.5	187.5
16	25	175	12.5	187.5	25	175	12.5	187.5
17	25	175	12.5	187.5	25	175	12.5	187.5
18	25	175	12.5	187.5	25	175	12.5	187.5
19	25	175	12.5	187.5	25	175	12.5	187.5
20	25	175	12.5	187.5	25	175	12.5	187.5
21	25	175	12.5	187.5	25	175	12.5	187.5

The time profiles for both net cash flow after tax and government tax revenue are therefore significantly different between the resource rent tax and the ad valorem royalty options.

The results for the specific royalty of $100 a tonne and $50 a tonne are identical to those for the ad valorem royalty of 10 per cent and 5 per cent, respectively, since price is assumed to be constant (and the policy settings were calibrated at the price of $1000 a tonne).

profitability assessments for the risk free hypothetical resource projects

The results for two profitability measures – the net present value (*NPV*) and internal rate of return (*irr*) – for the five hypothetical resource projects under the assumptions of lower and higher capital costs are presented in this section. The results for the present value of government resource taxation revenue under each policy option are also presented. The results for the projects before resource taxation and under the profit based royalties are given in table 12 and the results for the projects under the output based royalties are given in table 13.

All projects are assessed to be profitable under all resource taxation options (that is, the return to private investors is non-negative with $NPV \geq 0$ and $irr \geq 5$ per cent in all cases). Before resource taxation, under the assumption of lower (higher) capital costs, the net present value of the hypothetical resource projects increases from $8.9 million ($6.5 million) for project 1 to $1898 million ($1779 million) for project 5.

With lower capital costs, the net present value to private investors is larger for projects 1 and 2 under both resource rent tax options compared with the 10 per cent ad valorem royalty or $100 a tonne specific royalty – under a 5 per cent ad valorem royalty or $50 a tonne specific royalty, the net present value to private investors is increased and is equal to, or slightly higher than, the outcome for the resource rent tax with a 5 per cent risk premium in the threshold rate. For the larger projects 3–5, the net present value to private investors is lower under the profit based royalties than under the output based royalties.

That is, the smaller projects 1 and 2 are more profitable to the private investor under profit based royalties and the larger projects 3–5 are more profitable under the output based royalties levied at the higher rates – for output based royalties levied at the lower rates, the return to the private investor tends to be greater for all projects compared with the outcome under the profit based royalties, but there is also greater 'undertaxing' of highly profitable projects.

table 12 **profit based royalties** – net present value and internal rate of return for the hypothetical development projects lower and higher capital costs **a**

			Brown tax		resource rent tax: no risk premium		resource rent tax: 5% risk premium	
		net cash flow V	tax revenue V_{gov}	net cash flow after tax V_{inv}	tax revenue V_{gov}	net cash flow after tax V_{inv}	tax revenue V_{gov}	net cash flow after tax V_{inv}
lower capital costs								
net present value (in year 0 prices)								
project 1	$m	8.9	3.5	5.3	2.7	6.1	1.8	7.0
project 2	$m	44.3	17.7	26.6	15.7	28.6	12.0	32.3
project 3	$m	125.4	50.2	75.2	46.2	79.2	40.1	85.3
project 4	$m	324.3	129.7	194.6	123.7	200.6	113.8	210.5
project 5	$m	1897.6	759.0	1138.5	747.0	1150.5	725.7	1171.9
internal rate of return								
project 1	%	21.4	-	21.4	-	18.4	-	19.7
project 2	%	21.4	-	21.4	-	17.7	-	18.9
project 3	%	27.3	-	27.3	-	22.5	-	23.5
project 4	%	33.0	-	33.0	-	26.8	-	27.8
project 5	%	40.0	-	40.0	-	32.9	-	33.7
higher capital costs								
net present value (in year 0 prices)								
project 1	$m	6.5	2.6	3.9	1.8	4.7	0.4	6.1
project 2	$m	32.4	13.0	19.4	11.0	21.4	5.2	27.2
project 3	$m	101.6	40.6	60.9	36.6	64.9	27.4	74.2
project 4	$m	276.7	110.7	166.0	104.7	172.0	89.9	186.8
project 5	$m	1778.5	711.4	1067.1	699.4	1079.1	667.8	1110.7
internal rate of return								
project 1	%	15.1	-	15.1	-	13.2	-	14.7
project 2	%	15.1	-	15.1	-	12.7	-	14.1
project 3	%	20.2	-	20.2	-	16.6	-	17.8
project 4	%	25.0	-	25.0	-	20.3	-	21.3
project 5	%	31.9	-	31.9	-	26.4	-	27.1

a Both the net present value and the internal rate of return are given in year 0 and include data for the period from year 1 to the end of the mine life. Net present value is discounted at the risk free interest rate, assumed to be 5 per cent. The internal rate of return is given in nominal terms; the internal rate of return in real terms may be approximated by subtracting the annual inflation rate, assumed to be 3 per cent.

table 13 **output based royalties** – net present value and internal rate of return for the hypothetical development projects lower and higher capital costs **a**

		ad valorem royalty				specific royalty			
		10% royalty		5% royalty		$100/t royalty		$50/t royalty	
		tax revenue V_{gov}	net cash flow after tax V_{inv}	tax revenue V_{gov}	net cash flow after tax V_{inv}	tax revenue V_{gov}	net cash flow after tax V_{inv}	tax revenue V_{gov}	net cash flow after tax V_{inv}
lower capital costs									
net present value (in year 0 prices)									
project 1	$m	3.7	5.2	1.8	7.0	3.7	5.2	1.8	7.0
project 2	$m	18.4	25.9	9.2	35.1	18.4	25.9	9.2	35.1
project 3	$m	36.8	88.6	18.4	107.0	36.8	88.6	18.4	107.0
project 4	$m	73.5	250.8	36.8	287.5	73.5	250.8	36.8	287.5
project 5	$m	296.7	1600.8	148.4	1749.2	296.7	1600.8	148.4	1749.2
internal rate of return									
project 1	%	-	15.1	-	18.3	-	15.1	-	18.3
project 2	%	-	15.1	-	18.3	-	15.1	-	18.3
project 3	%	-	21.4	-	24.4	-	21.4	-	24.4
project 4	%	-	27.3	-	30.2	-	27.3	-	30.2
project 5	%	-	34.9	-	37.4	-	34.9	-	37.4
higher capital costs									
net present value (in year 0 prices)									
project 1	$m	3.7	2.8	1.8	4.6	3.7	2.8	1.8	4.6
project 2	$m	18.4	14.0	9.2	23.2	18.4	14.0	9.2	23.2
project 3	$m	36.8	64.8	18.4	83.2	36.8	64.8	18.4	83.2
project 4	$m	73.5	203.1	36.8	239.9	73.5	203.1	36.8	239.9
project 5	$m	296.7	1481.8	148.4	1630.2	296.7	1481.8	148.4	1630.2
internal rate of return									
project 1	%	-	9.6	-	12.4	-	9.6	-	12.4
project 2	%	-	9.6	-	12.4	-	9.6	-	12.4
project 3	%	-	15.1	-	17.7	-	15.1	-	17.7
project 4	%	-	20.2	-	22.6	-	20.2	-	22.6
project 5	%	-	27.8	-	29.8	-	27.8	-	29.8

a Both the net present value and the internal rate of return are given in year 0 and include data for the period from year 1 to the end of the mine life. Net present value is discounted at the risk free interest rate, assumed to be 5 per cent. The internal rate of return is given in nominal terms; the internal rate of return in real terms may be approximated by subtracting the annual inflation rate, assumed to be 3 per cent.

Under both resource rent tax options, when compared with the 10 per cent ad valorem royalty or $100 a tonne specific royalty, the present value of government tax revenue is lower for the smaller projects 1 and 2, but higher for the larger projects 3–5.

A further important efficiency aspect of the resource rent tax options is apparent from these simulation results. With a higher cost structure and a correspondingly lower net cash flow (given no change in revenue), the present value of government tax revenue is reduced for each project under profit based royalties but is unchanged under output based royalties. Thus, for example, with higher capital costs, projects 1–3 are now more profitable under the resource rent tax options than under either the 10 per cent ad valorem royalty or $100 a tonne specific royalty. For projects 4 and 5, project profitability remains higher under output based royalties than under profit based royalties.

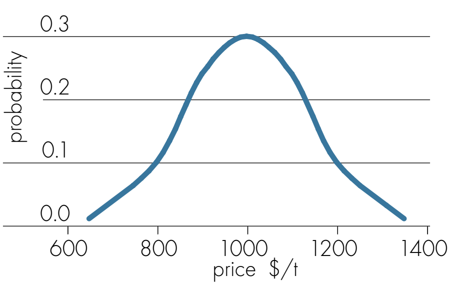
It should be emphasised that the simulation results are based on the assumptions for the policy settings in each resource taxation option. However, the results provide a useful indication of the nature of the impact of the alternative policy options on project profitability and government taxation revenue.

impact of resource taxation options on hypothetical resource projects under price risk

price risk and the risk premium

In this section, the implications of risk for project profitability assessments and government tax revenue are examined. For simplicity, the resource price is the only variable that is considered by private investors to be risky in the outlook. All other assumptions underlying the hypothetical resource projects and policy settings are as given in tables 7 and 8 respectively.

fig F **assumed probability distribution for the resource price**



Price risk is introduced into the project simulations in a relatively simple way. There are assumed to be seven possible price outcomes over the development and production stages of the resource projects. The probability distribution for the resource price that is assumed to be relevant to the outlook is given in table 14 and illustrated in figure F. Thus, for example, the probability that a price of $1000 a tonne will occur is assumed to be 30 per cent, while the price outcomes of $650 a tonne or $1350 a tonne are each assumed to occur with a probability of 1 per cent.

table 14 **assumed probability distribution for the resource price a**

price outcome	probability	price	percentage change from price in year 0
	no.	$/t	%
price 1	0.01	650	-35
price 2	0.10	800	-20
price 3	0.24	900	-10
price 4	0.30	1 000	0
price 5	0.24	1 100	10
price 6	0.10	1 200	20
price 7	0.01	1 350	35
price in year 0		1 000	
expected price	-	1 000	-

a For example, a price outcome of $1000 a tonne is assumed to have a probability of occurring of 0.3, or 30 per cent.

In the profitability assessments, risk averse private investors need to estimate the risk premium for each hypothetical resource project. In this study, the risk premium is assumed to be equal to the variance of the distribution of the net present values divided by the expected net present value – this is consistent with the approach used in other economic studies and discussed in Newbery and Stiglitz (1981). (In particular, the coefficient of relative risk aversion, *R*, is assumed to be 2; a higher value would indicate a higher degree of risk aversion and a lower value would indicate a lower degree of risk aversion.) As before, it would be possible to change any of these assumptions or undertake more detailed sensitivity analysis.

profitability assessments for the risky hypothetical resource projects

The focus in this section is on presenting the profitability assessments for the hypothetical resource projects under price risk assuming lower capital costs. The simulation results for the projects before resource taxation and under profit based royalties are presented in table 15 and the results for projects under output based royalties are presented in table 16.

In each table, the net present value and internal rate of return are given for each possible price outcome – that is, the results include the probability distribution of the two project profitability measures as well as the probability distribution of government taxation revenue under each resource taxation option. In addition, information is provided on two measures of the dispersion of the distribution of possible outcomes – the standard deviation (the square root of the variance) table 15 **profit based royalties** – profitability assessment of the hypothetical development projects under price risk lower capital costs

			Brown tax		resource rent tax: no risk premium		resource rent tax: 5% risk premium	
		net cash flow	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax
		V	V_{gov}	V_{inv}	V_{gov}	V_{inv}	V_{gov}	V_{inv}
project 1								
net present value by price outcome a								
price 1	$m	-4.0	-1.6	-2.4	0.0	-4.0	0.0	-4.0
price 2	$m	1.5	0.6	0.9	0.0	1.5	0.0	1.5
price 3	$m	5.2	2.1	3.1	1.3	3.9	0.1	5.1
price 4	$m	8.9	3.5	5.3	2.7	6.1	1.8	7.0
price 5	$m	12.5	5.0	7.5	4.2	8.3	3.5	9.1
price 6	$m	16.2	6.5	9.7	5.7	10.5	5.0	11.2
price 7	$m	21.7	8.7	13.0	7.9	13.8	7.3	14.4
internal rate of return by price outcome b								
price 1	%	-4.9	-	-4.9	-	-4.9	-	-4.9
price 2	%	8.1	-	8.1	-	8.1	-	8.1
price 3	%	15.1	-	15.1	-	13.4	-	15.0
price 4	%	21.4	-	21.4	-	18.4	-	19.7
price 5	%	27.3	-	27.3	-	23.1	-	24.3
price 6	%	33.0	-	33.0	-	27.8	-	28.8
price 7	%	41.1	-	41.1	-	34.5	-	35.4
measures of dispersion for the distribution of net present values c								
standard deviation	$m	4.5	1.8	2.7	1.7	2.8	1.8	2.9
coefficient of variation	no.	0.5	0.5	0.5	0.6	0.5	0.9	0.4
profitability measures d								
expected net present value	$m	8.9	3.5	5.3	2.8	6.1	2.0	6.9
risk premium	$m	2.3	-	1.4	-	1.3	-	1.2
certainty equivalent value	$m	6.5	-	3.9	-	4.8	-	5.7

continued...

table 15 **profit based royalties** – profitability assessment of the hypothetical development projects under price risk lower capital costs *continued*

			Brown tax		resource rent tax: no risk premium		resource rent tax: 5% risk premium	
		net cash flow	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax
		V	V_{gov}	V_{inv}	V_{gov}	V_{inv}	V_{gov}	V_{inv}
project 2								
net present value by price outcome a								
price 1	$m	-20.0	-8.0	-12.0	0.0	-20.0	0.0	-20.0
price 2	$m	7.5	3.0	4.5	1.0	6.5	0.0	7.5
price 3	$m	25.9	10.4	15.6	8.4	17.6	3.5	22.4
price 4	$m	44.3	17.7	26.6	15.7	28.6	12.0	32.3
price 5	$m	62.7	25.1	37.6	23.1	39.6	20.0	42.7
price 6	$m	81.1	32.4	48.6	30.4	50.6	27.8	53.3
price 7	$m	108.7	43.5	65.2	41.5	67.2	39.2	69.4
internal rate of return by price outcome b								
price 1	%	-4.9	-	-4.9	-	-4.9	-	-4.9
price 2	%	8.1	-	8.1	-	7.8	-	8.1
price 3	%	15.1	-	15.1	-	12.8	-	14.3
price 4	%	21.4	-	21.4	-	17.7	-	18.9
price 5	%	27.3	-	27.3	-	22.5	-	23.5
price 6	%	33.0	-	33.0	-	27.0	-	28.0
price 7	%	41.1	-	41.1	-	33.6	-	34.5
measures of dispersion for the distribution of net present values c								
standard deviation	$m	22.7	9.1	13.6	8.8	13.9	9.0	14.0
coefficient of variation	no.	0.5	0.5	0.5	0.6	0.5	0.7	0.4
profitability measures d								
expected net present value	$m	44.3	17.7	26.6	15.8	28.5	12.4	31.9
risk premium	$m	11.6	-	7.0	-	6.8	-	6.1
certainty equivalent value	$m	32.7	-	19.6	-	21.7	-	25.7

continued...

table 15 **profit based royalties –** profitability assessment of the hypothetical **development projects under price risk** lower capital costs *continued*

			Brown tax		resource rent tax: no risk premium		resource rent tax: 5% risk premium	
		net cash flow	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax
		V	V_{gov}	V_{inv}	V_{gov}	V_{inv}	V_{gov}	V_{inv}
project 3								
net present value by price outcome a								
price 1	$m	-3.3	-1.3	-2.0	0.0	-3.3	0.0	-3.3
price 2	$m	51.8	20.7	31.1	16.7	35.1	7.1	44.7
price 3	$m	88.6	35.4	53.2	31.4	57.2	24.1	64.5
price 4	$m	125.4	50.2	75.2	46.2	79.2	40.1	85.3
price 5	$m	162.2	64.9	97.3	60.9	101.3	55.7	106.5
price 6	$m	198.9	79.6	119.4	75.6	123.4	70.9	128.0
price 7	$m	254.1	101.6	152.4	97.6	156.4	93.6	160.5
internal rate of return by price outcome b								
price 1	%	4.3	-	4.3	-	4.3	-	4.3
price 2	%	15.1	-	15.1	-	12.8	-	14.3
price 3	%	21.4	-	21.4	-	17.7	-	18.9
price 4	%	27.3	-	27.3	-	22.5	-	23.5
price 5	%	33.0	-	33.0	-	27.0	-	28.0
price 6	%	38.5	-	38.5	-	31.5	-	32.4
price 7	%	46.5	-	46.5	-	37.8	-	38.8
measures of dispersion for the distribution of net present values c								
standard deviation	$m	45.4	18.2	27.2	18.0	27.4	19.2	26.3
coefficient of variation	no.	0.4	0.4	0.4	0.4	0.3	0.5	0.3
profitability measures d								
expected net present value	$m	125.4	50.2	75.2	46.2	79.2	39.9	85.5
risk premium	$m	16.4	–	9.9	–	9.5	–	8.1
certainty equivalent value	$m	108.9	–	65.4	–	69.7	–	77.4

table 15 **profit based royalties** – profitability assessment of the hypothetical development projects under price risk lower capital costs *continued*

			Brown tax		resource rent tax: no risk premium		resource rent tax: 5% risk premium	
		net cash flow	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax
		V	V_{gov}	V_{inv}	V_{gov}	V_{inv}	V_{gov}	V_{inv}
project 4								
net present value by price outcome a								
price 1	$m	66.9	26.8	40.1	20.8	46.1	0.0	66.9
price 2	$m	177.2	70.9	106.3	64.9	112.3	51.0	126.2
price 3	$m	250.8	100.3	150.5	94.3	156.5	82.8	168.0
price 4	$m	324.3	129.7	194.6	123.7	200.6	113.8	210.5
price 5	$m	397.8	159.1	238.7	153.1	244.7	144.3	253.6
price 6	$m	471.4	188.6	282.8	182.6	288.8	174.6	296.8
price 7	$m	581.7	232.7	349.0	226.7	355.0	219.5	362.2
internal rate of return by price outcome b								
price 1	%	11.7	-	11.7	-	10.1	-	11.7
price 2	%	21.4	-	21.4	-	17.6	-	18.7
price 3	%	27.3	-	27.3	-	22.3	-	23.3
price 4	%	33.0	-	33.0	-	26.8	-	27.8
price 5	%	38.5	-	38.5	-	31.3	-	32.1
price 6	%	43.8	-	43.8	-	35.5	-	36.4
price 7	%	51.7	-	51.7	-	41.8	-	42.6
measures of dispersion for the distribution of net present values c								
standard deviation	$m	90.8	36.3	54.5	36.3	54.5	38.2	52.6
coefficient of variation	no.	0.3	0.3	0.3	0.3	0.3	0.3	0.2
profitability measures d								
expected net present value	$m	324.3	129.7	194.6	123.7	200.6	113.4	210.9
risk premium	$m	25.4	-	15.3	-	14.8	-	13.1
certainty equivalent value	$m	298.9	-	179.3	-	185.8	-	197.8

continued...

table 15 **profit based royalties – profitability assessment of the hypothetical development projects under price risk** lower capital costs *continued*

			Brown tax		resource rent tax no risk premium		resource rent tax 5% risk premium	
		net cash flow	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax
		V	V_{gov}	V_{inv}	V_{gov}	V_{inv}	V_{gov}	V_{inv}
project 5								
net present value by price outcome a								
price 1	$m	351.1	140.5	210.7	128.5	222.7	90.7	260.4
price 2	$m	626.9	250.8	376.1	238.8	388.1	211.0	415.9
price 3	$m	810.8	324.3	486.5	312.3	498.5	288.4	522.4
price 4	$m	994.6	397.8	596.8	385.8	608.8	364.5	630.1
price 5	$m	1 178.5	471.4	707.1	459.4	719.1	440.1	738.4
price 6	$m	1 362.3	544.9	817.4	532.9	829.4	514.9	847.4
price 7	$m	1 638.1	655.2	982.9	643.2	994.9	627.2	1 010.9
internal rate of return by price outcome b								
price 1	%	18.3	–	18.3	–	15.0	–	16.2
price 2	%	27.3	–	27.3	–	22.2	–	23.1
price 3	%	33.0	–	33.0	–	26.7	–	27.6
price 4	%	38.5	–	38.5	–	31.1	–	32.0
price 5	%	43.8	–	43.8	–	35.4	–	36.3
price 6	%	49.1	–	49.1	–	39.6	–	40.4
price 7	%	56.9	–	56.9	–	45.8	–	46.6
measures of dispersion for the distribution of net present values c								
standard deviation	$m	227.0	90.8	136.2	90.8	136.2	93.9	133.1
coefficient of variation	no.	0.2	0.2	0.2	0.2	0.2	0.3	0.2
profitability measures d								
expected net present value	$m	994.6	397.8	596.8	385.8	608.8	363.9	630.7
risk premium	$m	51.8	–	31.1	–	30.5	–	28.1
certainty equivalent value	$m	942.8	–	565.7	–	578.3	–	602.6

a Net present value is given in year 0 prices and includes data for the period from year 1 to the end of the mine life. Net present value is discounted at the risk free interest rate, assumed to be 5 per cent. **b** The internal rate of return is given in year 0 in nominal terms and includes data for the period from year 1 to the end of the mine life. The internal rate of return in real terms may be approximated by subtracting the annual inflation rate, assumed to be 3 per cent. **c** Standard deviation is the square root of the variance. The coefficient of variation is the standard deviation divided by the expected net present value (or mean of the distribution of net present values). **d** See main text for an explanation of these variables.

table 16 **output based royalties – profitability assessment of the hypothetical development projects under price risk** lower capital costs

		ad valorem royalty				specific royalty			
		10% royalty		5% royalty		\$100/t royalty		\$50/t royalty	
		tax revenue	net cash flow after tax	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax
		V_{gov}	V_{inv}	V_{gov}	V_{inv}	V_{gov}	V_{inv}	V_{gov}	V_{inv}
project 1									
net present value by price outcome a									
price 1	\$m	2.4	-6.4	1.2	-5.2	3.7	-7.7	1.8	-5.8
price 2	\$m	2.9	-1.4	1.5	0.0	3.7	-2.2	1.8	-0.3
price 3	\$m	3.3	1.9	1.7	3.5	3.7	1.5	1.8	3.3
price 4	\$m	3.7	5.2	1.8	7.0	3.7	5.2	1.8	7.0
price 5	\$m	4.0	8.5	2.0	10.5	3.7	8.9	1.8	10.7
price 6	\$m	4.4	11.8	2.2	14.0	3.7	12.5	1.8	14.4
price 7	\$m	5.0	16.8	2.5	19.2	3.7	18.1	1.8	19.9
internal rate of return by price outcome b									
price 1	%	-	-13.1	-	-8.7	-	-19.6	-	-11.0
price 2	%	-	1.8	-	5.1	-	0.0	-	4.3
price 3	%	-	8.9	-	12.1	-	8.1	-	11.7
price 4	%	-	15.1	-	18.3	-	15.1	-	18.3
price 5	%	-	20.8	-	24.1	-	21.4	-	24.4
price 6	%	-	26.2	-	29.6	-	27.3	-	30.2
price 7	%	-	33.8	-	37.5	-	35.7	-	38.5
measures of dispersion for the distribution of net present values c									
standard deviation	\$m	0.5	4.1	0.2	4.3	0.0	4.5	0.0	4.5
coefficient of variation	no.	0.1	0.8	0.1	0.6	0.0	0.9	0.0	0.6
profitability measures d									
expected net present value	\$m	3.7	5.2	1.8	7.0	3.7	5.2	1.8	7.0
risk premium	\$m	-	3.2	-	2.6	-	4.0	-	2.9
certainty equivalent value	\$m	-	2.0	-	4.4	-	1.2	-	4.1

continued...

table 16 **output based royalties** – profitability assessment of the hypothetical development projects under price risk lower capital costs *continued*

		ad valorem royalty				specific royalty			
		10% royalty		5% royalty		$100/t royalty		$50/t royalty	
		tax revenue	net cash flow after tax	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax
		V_{gov}	V_{inv}	V_{gov}	V_{inv}	V_{gov}	V_{inv}	V_{gov}	V_{inv}
project 2									
net present value by price outcome a									
price 1	$m	12.0	-32.0	6.0	-26.0	18.4	-38.4	9.2	-29.2
price 2	$m	14.7	-7.2	7.4	0.2	18.4	-10.8	9.2	-1.7
price 3	$m	16.5	9.4	8.3	17.6	18.4	7.5	9.2	16.7
price 4	$m	18.4	25.9	9.2	35.1	18.4	25.9	9.2	35.1
price 5	$m	20.2	42.5	10.1	52.6	18.4	44.3	9.2	53.5
price 6	$m	22.1	59.0	11.0	70.0	18.4	62.7	9.2	71.9
price 7	$m	24.8	83.8	12.4	96.2	18.4	90.3	9.2	99.5
internal rate of return by price outcome b									
price 1	%	-	-13.1	-	-8.7	-	-19.6	-	-11.0
price 2	%	-	1.8	-	5.1	-	0.0	-	4.3
price 3	%	-	8.9	-	12.1	-	8.1	-	11.7
price 4	%	-	15.1	-	18.3	-	15.1	-	18.3
price 5	%	-	20.8	-	24.1	-	21.4	-	24.4
price 6	%	-	26.2	-	29.6	-	27.3	-	30.2
price 7	%	-	33.8	-	37.5	-	35.7	-	38.5
measures of dispersion for the distribution of net present values c									
standard deviation	$m	2.3	20.4	1.1	21.6	0.0	22.7	0.0	22.7
coefficient of variation	no.	0.1	0.8	0.1	0.6	0.0	0.9	0.0	0.6
profitability measures d									
expected net present value	$m	18.4	25.9	9.2	35.1	18.4	25.9	9.2	35.1
risk premium	$m	-	16.1	-	13.2	-	19.9	-	14.7
certainty equivalent value	$m	-	9.8	-	21.9	-	6.0	-	20.4

continued...

table 16 **output based royalties –** profitability assessment of the hypothetical development projects under price risk lower capital costs *continued*

		ad valorem royalty				specific royalty			
		10% royalty		5% royalty		$100/t royalty		$50/t royalty	
		tax revenue	net cash flow after tax	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax
		V_{gov}	V_{inv}	V_{gov}	V_{inv}	V_{gov}	V_{inv}	V_{gov}	V_{inv}
project 3									
net present value by price outcome a									
price 1	$m	23.9	-27.2	12.0	-15.3	36.8	-40.1	18.4	-21.7
price 2	$m	29.4	22.4	14.7	37.1	36.8	15.1	18.4	33.5
price 3	$m	33.1	55.5	16.5	72.1	36.8	51.8	18.4	70.2
price 4	$m	36.8	88.6	18.4	107.0	36.8	88.6	18.4	107.0
price 5	$m	40.4	121.7	20.2	141.9	36.8	125.4	18.4	143.8
price 6	$m	44.1	154.8	22.1	176.9	36.8	162.2	18.4	180.5
price 7	$m	49.6	204.4	24.8	229.3	36.8	217.3	18.4	235.7
internal rate of return by price outcome b									
price 1	%	-	-1.4	-	1.6	-	-4.9	-	0.0
price 2	%	-	9.6	-	12.4	-	8.1	-	11.7
price 3	%	-	15.8	-	18.6	-	15.1	-	18.3
price 4	%	-	21.4	-	24.4	-	21.4	-	24.4
price 5	%	-	26.7	-	29.9	-	27.3	-	30.2
price 6	%	-	31.9	-	35.2	-	33.0	-	35.7
price 7	%	-	39.3	-	42.9	-	41.1	-	43.8
measures of dispersion for the distribution of net present values c									
standard deviation	$m	4.5	40.9	2.3	43.1	0.0	45.4	0.0	45.4
coefficient of variation	no.	0.1	0.5	0.1	0.4	0.0	0.5	0.0	0.4
profitability measures d									
expected net present value	$m	36.8	88.6	18.4	107.0	36.8	88.6	18.4	107.0
risk premium	$m	-	18.8	-	17.4	-	23.3	-	19.3
certainty equivalent value	$m	-	69.8	-	89.6	-	65.3	-	87.7

continued...

table 16 **output based royalties** – profitability assessment of the hypothetical development projects under price risk lower capital costs *continued*

		ad valorem royalty				specific royalty			
		10% royalty		5% royalty		$100/t royalty		$50/t royalty	
		tax revenue	net cash flow after tax	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax	tax revenue	net cash flow after tax
		V_{gov}	V_{inv}	V_{gov}	V_{inv}	V_{gov}	V_{inv}	V_{gov}	V_{inv}
project 4									
net present value by price outcome a									
price 1	$m	47.8	19.1	23.9	43.0	73.5	-6.6	36.8	30.1
price 2	$m	58.8	118.4	29.4	147.8	73.5	103.7	36.8	140.5
price 3	$m	66.2	184.6	33.1	217.7	73.5	177.2	36.8	214.0
price 4	$m	73.5	250.8	36.8	287.5	73.5	250.8	36.8	287.5
price 5	$m	80.9	317.0	40.4	357.4	73.5	324.3	36.8	361.1
price 6	$m	88.2	383.1	44.1	427.3	73.5	397.8	36.8	434.6
price 7	$m	99.3	482.4	49.6	532.1	73.5	508.2	36.8	544.9
internal rate of return by price outcome a									
price 1	%	–	7.0	–	9.4	–	4.3	–	8.1
price 2	%	–	16.4	–	18.9	–	15.1	–	18.3
price 3	%	–	22.0	–	24.7	–	21.4	–	24.4
price 4	%	–	27.3	–	30.2	–	27.3	–	30.2
price 5	%	–	32.4	–	35.5	–	33.0	–	35.7
price 6	%	–	37.4	–	40.6	–	38.5	–	41.1
price 7	%	–	44.6	–	48.2	–	46.5	–	49.1
measures of dispersion for the distribution of net present values c									
standard deviation	$m	9.1	81.7	4.5	86.3	0.0	90.8	0.0	90.8
coefficient of variation	no.	0.1	0.3	0.1	0.3	0.0	0.4	0.0	0.3
profitability measures d									
expected net present value	$m	73.5	250.8	36.8	287.5	73.5	250.8	36.8	287.5
risk premium	$m	–	26.6	–	25.9	–	32.9	–	28.7
certainty equivalent value	$m	–	224.1	–	261.6	–	217.9	–	258.9

continued...

table 16 **output based royalties** – profitability assessment of the hypothetical development projects under price risk lower capital costs *continued*

		ad valorem royalty				specific royalty			
		10% royalty		5% royalty		$100/t royalty		$50/t royalty	
		tax revenue V_{gov}	net cash flow after tax V_{inv}	tax revenue V_{gov}	net cash flow after tax V_{inv}	tax revenue V_{gov}	net cash flow after tax V_{inv}	tax revenue V_{gov}	net cash flow after tax V_{inv}
project 5									
net present value by price outcome a									
price 1	$m	119.5	231.6	59.8	291.4	183.9	167.3	91.9	259.2
price 2	$m	147.1	479.8	73.5	553.4	183.9	443.1	91.9	535.0
price 3	$m	165.5	645.3	82.7	728.0	183.9	626.9	91.9	718.8
price 4	$m	183.9	810.8	91.9	902.7	183.9	810.8	91.9	902.7
price 5	$m	202.2	976.2	101.1	1077.3	183.9	994.6	91.9	1086.5
price 6	$m	220.6	1141.7	110.3	1252.0	183.9	1178.5	91.9	1270.4
price 7	$m	248.2	1389.9	124.1	1514.0	183.9	1454.2	91.9	1546.2
internal rate of return by price outcome b									
price 1	%	–	14.1	–	16.2	–	11.7	–	15.1
price 2	%	–	22.6	–	25.0	–	21.4	–	24.4
price 3	%	–	27.9	–	30.5	–	27.3	–	30.2
price 4	%	–	33.0	–	35.7	–	33.0	–	35.7
price 5	%	–	37.9	–	40.9	–	38.5	–	41.1
price 6	%	–	42.7	–	45.9	–	43.8	–	46.5
price 7	%	–	49.9	–	53.4	–	51.7	–	54.3
measures of dispersion for the distribution of net present values c									
standard deviation	$m	22.7	204.3	11.4	215.7	0.0	227.0	0.0	227.0
coefficient of variation	no.	0.1	0.3	0.1	0.2	0.0	0.3	0.0	0.3
profitability measures d									
expected net present value	$m	183.9	810.8	91.9	902.7	183.9	810.8	91.9	902.7
risk premium	$m	–	51.5	–	51.5	–	63.6	–	57.1
certainty equivalent value	$m	–	759.3	–	851.2	–	747.2	–	845.6

a Net present value is given in year 0 prices and includes data for the period from year 1 to the end of the mine life. Net present value is discounted at the risk free interest rate, assumed to be 5 per cent. **b** The internal rate of return is given in year 0 in nominal terms and includes data for the period from year 1 to the end of the mine life. The internal rate of return in real terms may be approximated by subtracting the annual inflation rate, assumed to be 3 per cent. **c** Standard deviation is the square root of the variance. The coefficient of variation is the standard deviation divided by the expected net present value (or mean of the distribution of net present values). **d** See main text for an explanation of these variables.

and the coefficient of variation (the standard deviation divided by the mean or expected net present value). The coefficient of variation is a standardised measure of dispersion that may be used to compare the variability of possible outcomes across projects – a higher coefficient of variation indicates the distribution of possible outcomes is more dispersed (a value of 0 indicates there is no variation in possible outcomes). The expected net present value is reported in all cases for the return to both the private investor and the government, and the risk premium and certainty equivalent value is reported for the return to the private investor (that is, for the net cash flow before and after resource taxation).

All projects are assessed to be profitable under each resource taxation option for the degree of risk aversion that is assumed to characterise the private investor's attitude toward risk.

The impact of the resource taxation options on the probability distribution of the project profitability measures, net present value and internal rate of return, is illustrated in figures G–K for projects 1–5 respectively. (Note the internal rate of return under the Brown tax is identical to the internal rate of return before tax.)

In each case, the net present value to the private investor (and corresponding internal rate of return) increases with the price outcome. If the lowest price outcome (price 1) occurred, project 1 would not be profitable either before resource taxation or under any of the resource taxation options included here. If price 2 occurred, project 1 would not be profitable under the output based royalties (except for the 5 per cent ad valorem royalty), but would be profitable under profit based royalties. Compared with the output based royalties, the return to the private investor under the resource rent tax options tends to be higher for lower price outcomes and lower for higher price outcomes.

The resource rent tax is not triggered for project 1 under either of the lowest two price outcomes (price 1 and 2). Apart from the lowest profit outcomes when the resource rent tax is not triggered, the present value of government tax revenue increases with the price outcome. The present value of government tax revenue increases with the price outcome under the ad valorem royalty options, but is constant under the specific royalty options. Compared with the output based royalties, the present value of government tax revenue under the resource rent tax options tends to be lower for lower price outcomes and higher for higher price outcomes.

The coefficient of variation is a useful measure of the variability of possible outcomes for both project profitability and the return to the government. Under the resource rent tax options, the variability in possible outcomes for government tax revenue is greater than the variability in possible outcomes for project profitability. By contrast, the variability in possible outcomes for government tax revenue for any given project tends to be low under output based royalties and the variability in possible outcomes for project profitability is increased.

For projects 1 and 2, the expected net present value to private investors is higher under the resource rent tax options than under the 10 per cent ad valorem royalty or $100 a tonne specific royalty. For projects 3–5, the expected net present value to the private investor is higher under output based royalties than under the resource rent tax options.

The simulation results illustrate the risk sharing characteristics of profit based royalties and the risk increasing characteristics of output based royalties. Compared with the risk premium in each project before resource taxation, the risk premium is reduced under the profit based royalties and is increased under the output based royalties (with the exception of the ad valorem royalty options in project 5).

The certainty equivalent value of each hypothetical resource project is a measure of project profitability when private investors are assumed to be risk averse. As discussed earlier, the certainty equivalent value is equal to the expected net present value less the risk premium that private investors require to compensate them for the risks incurred when investing in a risky resource project. The certainty equivalent value is higher under profit based royalties than under output based royalties for the smaller projects 1 and 2. The certainty equivalent value tends to be relatively higher under output based royalties for the larger more profitable projects, particularly projects 4 and 5.

Under the assumption of higher capital costs, based on the certainty equivalent value, all projects are still assessed to be profitable under the profit based royalties. However, projects 1 and 2 are unprofitable under the 10 per cent ad valorem royalty and $100 a tonne specific royalty – that is, these projects switch from being economic before tax to uneconomic after tax. Under the 5 per cent ad valorem royalty and $50 a tonne specific royalty, the certainty equivalent value of projects 1 and 2 is reduced significantly but remains positive in each case ($0.6 million and $0.2 million, respectively, for project 1, and $3.2 million and $1.0 million, respectively, for project 2). The larger projects 3–5 are assessed to be profitable under output based royalties under the assumption of higher capital costs.

fig G **project 1 with price risk –** probability distribution of profitability measures for net cash flow before and after tax lower capital costs

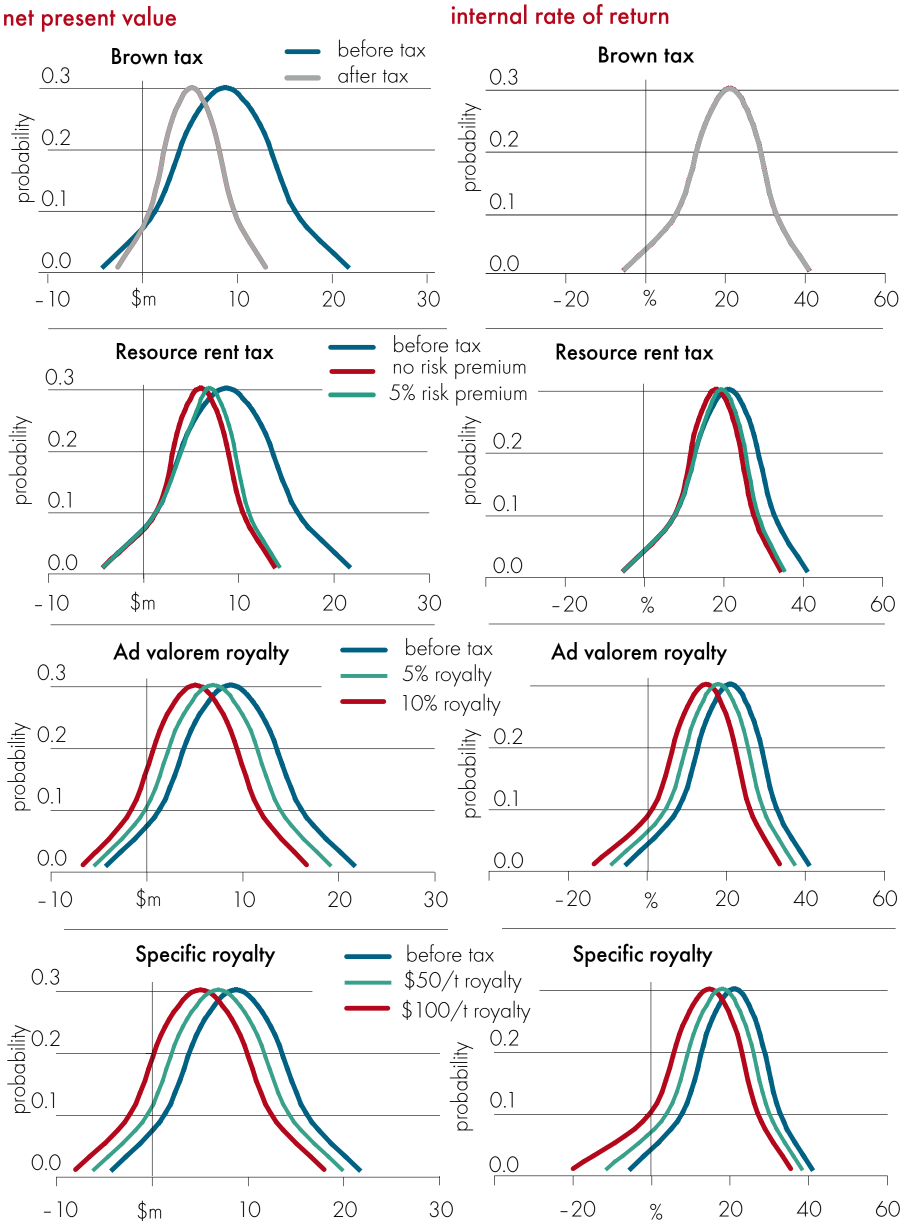


fig H **project 2 with price risk –** probability distribution of profitability measures for net cash flow before and after tax lower capital costs

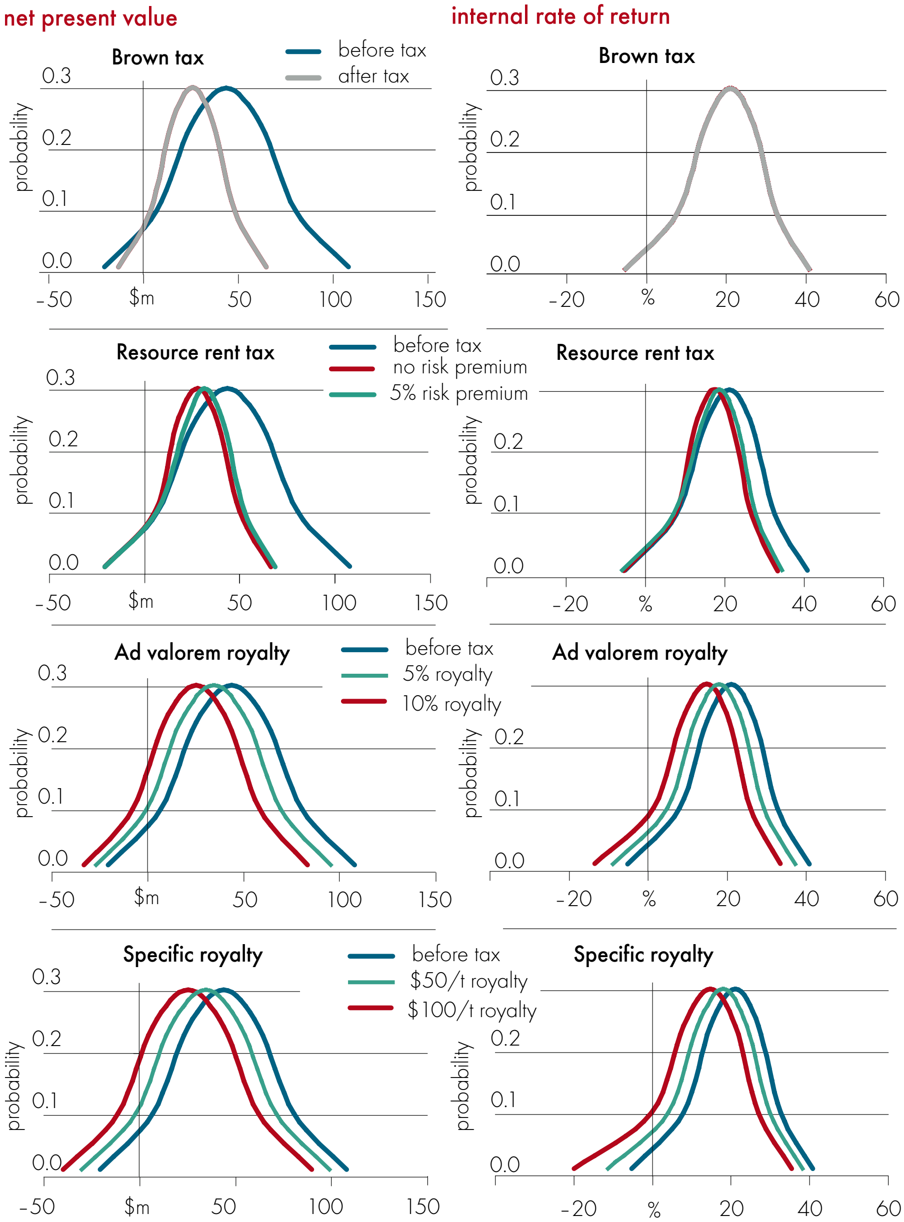


fig I **project 3 with price risk –** probability distribution of profitability measures for net cash flow before and after tax lower capital costs

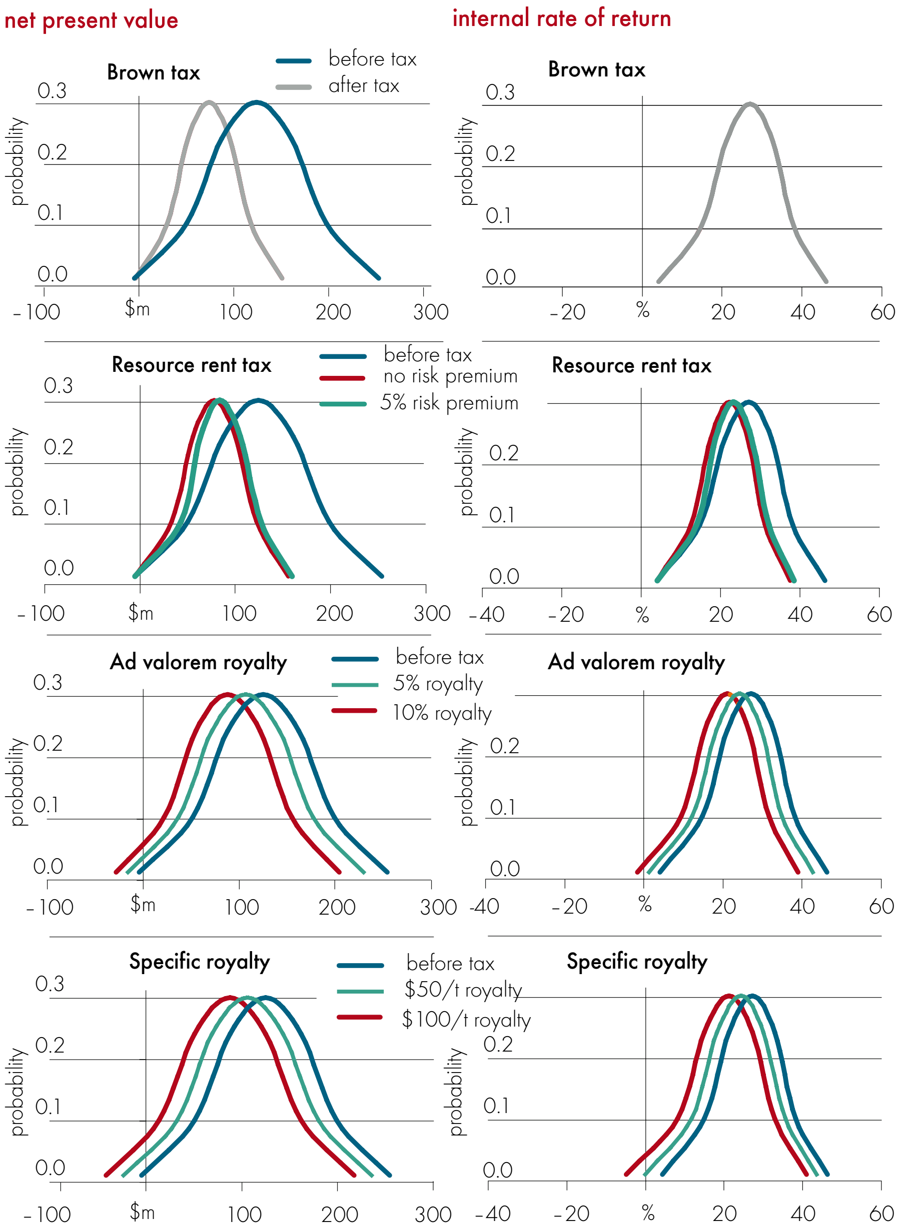


fig J **project 4 with price risk –** probability distribution of profitability measures for net cash flow before and after tax lower capital costs

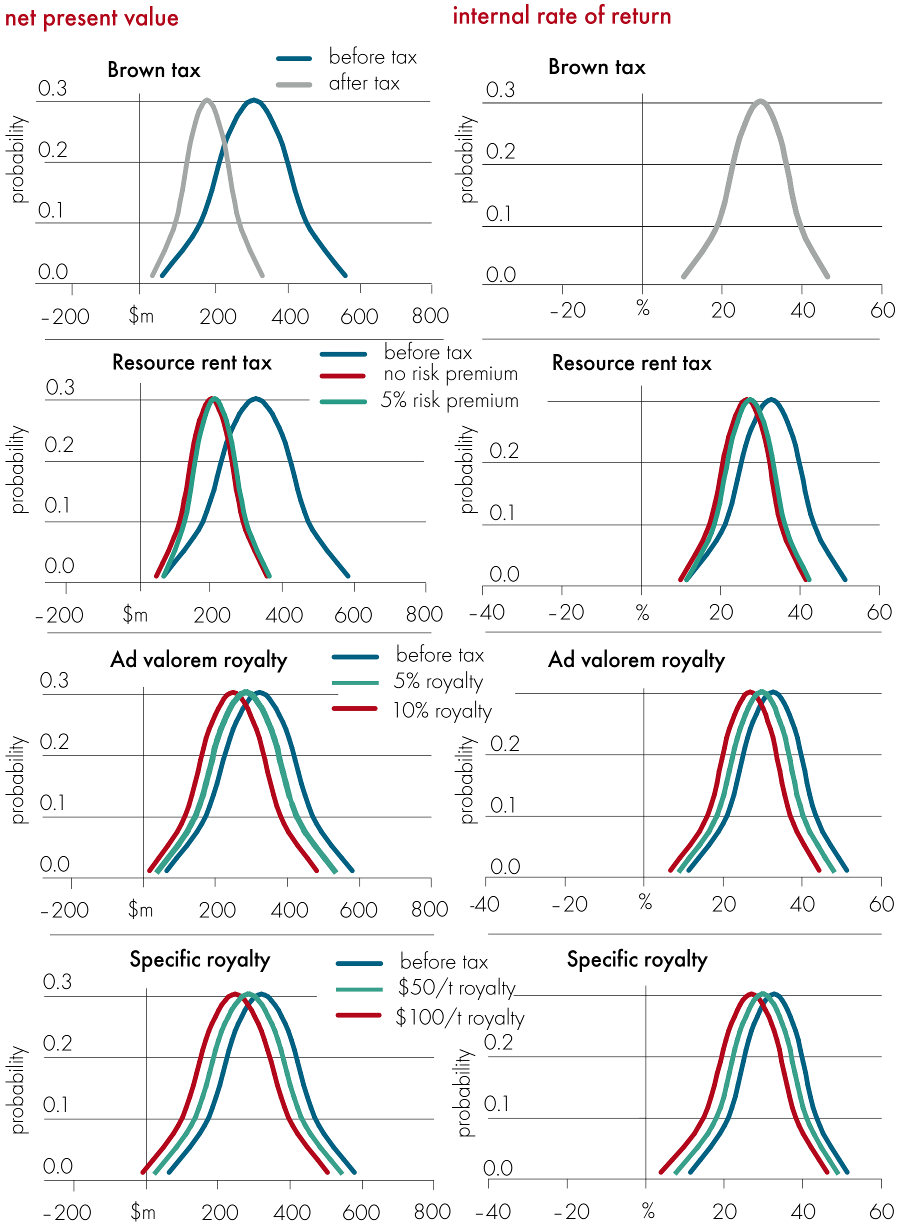
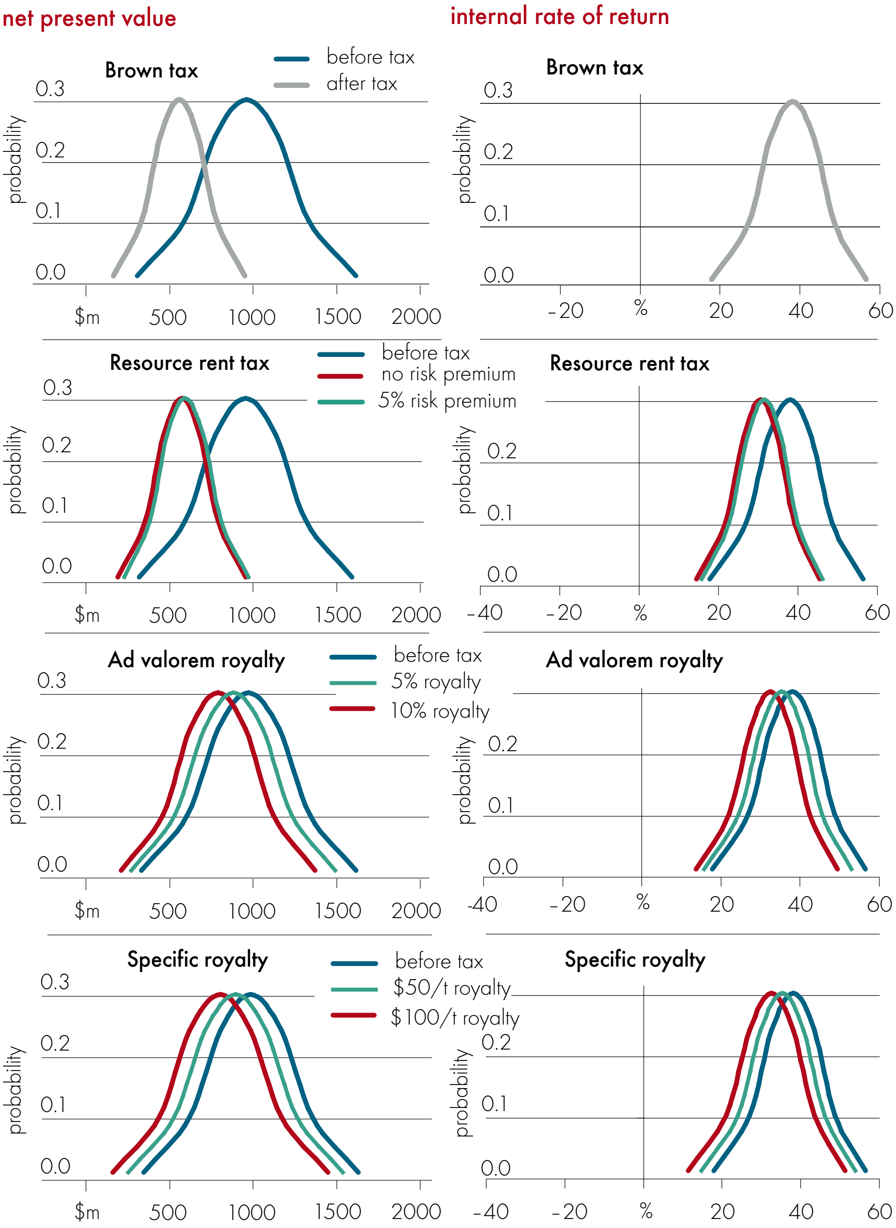


fig K **project 5 with price risk –** probability distribution of profitability measures for net cash flow before and after tax lower capital costs



5

implications for resource taxation policy in Australia

By international standards, Australia has substantial natural wealth in the form of mineral resources (see table 1). The objective in resource taxation policy is to enable Australian, state and territory governments to collect a reasonable return from the extraction of these mineral resources by the private sector at a reasonably low cost to both the private sector and government. Any assessment of the cost of resource taxation policy should take into account private and public administrative costs as well as the impact on industry investment and production decisions (that is, the efficiency implications of resource taxation policy).

In this chapter, future directions for resource taxation policy in Australia are examined. With the major exception of the petroleum resource rent tax, there is currently a strong reliance on output based royalties in Australia, mainly ad valorem royalties (see chapter 2).

From the theoretical analysis in chapter 3 and the simulations of a range of hypothetical resource projects in chapter 4, it is apparent that switching from output based royalties to a profit based royalty in Australia would be likely to result in significant efficiency gains although this would be achieved at a higher administrative cost. The practical experience of the Australian Government in administering the petroleum resource rent tax is critical in the assessment of the administrative costs associated with extending a profit based royalty to onshore mineral resources in Australia.

government resource taxation revenue and major efficiency implications of key policy options

To examine future directions for resource taxation policy in Australia, it is useful to note some highlights from the economic assessment of key resource taxation policy options in chapters 3 and 4. From a practical policy perspective, the main policy options considered here are the resource rent tax and the ad valorem royalty.

government tax take

For a given government tax take and ignoring administrative costs, the impact of profit based royalties and output based royalties will be similar only if all resource projects are identical and profitable (that is, there are no marginal projects), and production, price and project profitability do not change over time (fiscal settings in each policy option may be calibrated such that the government tax take is identical in each period).

Clearly, in practice, resource projects tend to vary widely in terms of the size and quality of the ore deposit (or fossil fuel field) both within any given time period as well as over time. When the geological and economic characteristics of resource projects vary widely, project profitability is also likely to vary widely. With economies of scale, for example, the profit from extracting a unit of the resource is higher for larger mines (that is, project profitability increases with mine size). More generally, project profitability will vary with significant differences in the quality of ore deposits. The mix of resource projects will change over time as ore deposits are exhausted and new ore deposits are discovered and brought into production.

Under the resource rent tax, the government aims to collect a constant percentage of the resource rent of each resource project. That is, the government tax take varies according to project profits in excess of the specified threshold rate of return.

Under an output based royalty, an important problem facing policy makers is to set a royalty rate that is expected to collect sufficient royalty revenue to justify the imposition of the royalty but to make a subjective judgment about the negative impact on the profitability of low profit or marginal resource projects and a possible shortfall from high profit projects (compared with the outcome under profit based royalties).

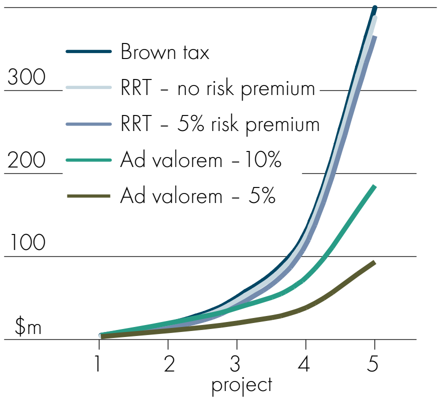
Provided there exists a range of low profit and high profit resource projects, output based royalties tend to overtax low profit projects and to undertax high profit projects. The government tax take will be too high for low profit projects with some becoming uneconomic as a consequence (and the government tax take reduced to zero for these projects), and too low for high profit projects.

These features of profit based royalties and output based royalties may be illustrated using the simulations of hypothetical resource projects presented in chapter 4. An overview of the government tax take under key policy options for five hypothetical resource development projects (lower capital costs assumption) is presented in figure L. These results highlight the extent to which larger high profit projects may be undertaxed under an ad valorem royalty compared with the outcome under profit based royalties (the results presented later in this section on the certainty equivalent value or risk adjusted return to the private investor highlight the impact of overtaxing low profit projects).

The Brown tax is included as a benchmark royalty arrangement but, as noted previously, is not regarded as a feasible policy option for implementation since cash rebates are provided to private investors in years of negative net cash flow (the Brown tax rate is 40 per cent). Two resource rent tax (RRT) options are included – no risk premium and a 5 per cent risk premium in the threshold rate – to indicate the nature of the impact of a risk premium in the fiscal settings (for a given tax rate of 40 per cent).

The resource rent tax option with a 5 per cent risk premium in the threshold rate approximates the Australian Government's petroleum resource rent tax system since this is the threshold rate for general project expenditures – the risk premium compensates private investors to some extent for the risk of losses incurred in failed development projects since these losses are not deductible for petroleum resource rent tax assessment purposes (it should be noted the simulations do not include some other aspects of the petroleum resource rent tax such as companywide deductibility of exploration expenditure and the treatment of exploration expenditure by new companies).

fig L **summary of government tax take under key policy options for hypothetical resource projects, lower capital costs** in present value terms



Two ad valorem royalty options are also included in figure L – royalty rates of 10 per cent and 5 per cent – to provide an indication of the nature of the impact of different fiscal settings.

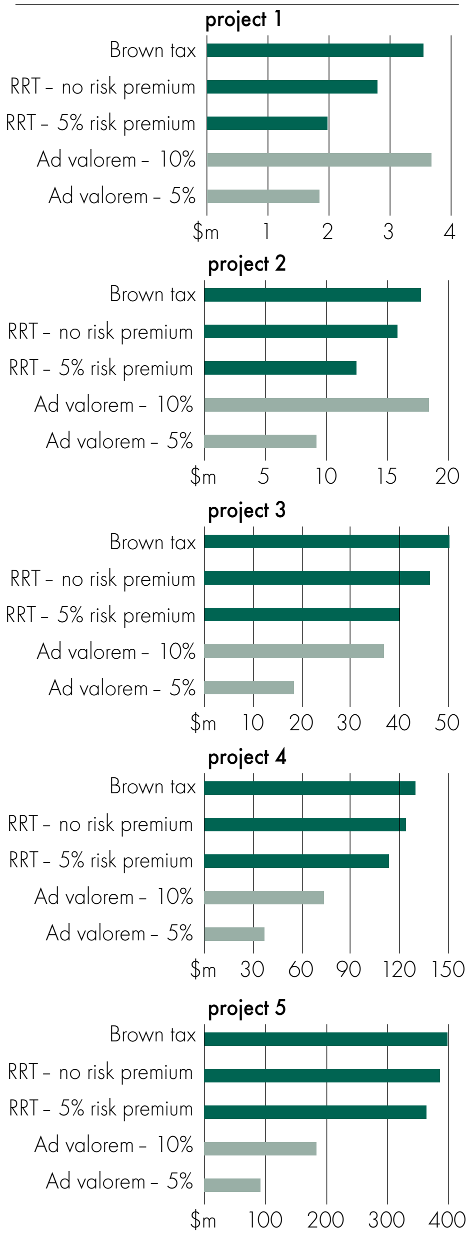
The government tax take under each policy option is presented separately for each hypothetical resource development project in figure M to better understand the problem facing policymakers in setting an ad valorem royalty rate when project profitability varies widely. The government tax take is given by the expected present value of resource taxation revenue over the project life.

For the small low profit project 1, the government tax take under the 10 per cent ad valorem royalty is slightly higher than that for the Brown tax, while the government tax take under the 5 per cent ad valorem royalty is slightly below that for the resource rent tax with a 5 per cent risk premium (the proxy for the petroleum resource rent tax). The government tax take for the resource rent tax with no risk premium falls between the outcomes for the Brown tax and the resource rent tax with a 5 per cent risk premium.

The ranking of policy options based on government tax take is unchanged for project 2, but is altered significantly for the remaining projects with the government tax take under both ad valorem royalties consistently below the government tax take under the profit based royalties.

For the larger high profit project 5, the government tax take under the 10 per cent ad valorem royalty is around half of the government tax take under the resource rent tax with a 5 per cent risk premium.

fig M **government tax take under key policy options for each hypothetical resource project** lower capital costs in present value terms



risk premium in project profitability assessments

Private investment decisions are assumed to be influenced by the perceived risks in potential resource projects as well as the attitudes of private investors toward incurring these risks. Risk averse private investors are generally assumed to adopt a relatively conservative approach in assessing the profitability of potential resource projects. In the economic framework adopted in this study, the decision rule for project profitability assessments by risk averse private investors is based on the certainty equivalent value – this is the expected net present value of a resource project less a risk premium that provides private investors with sufficient compensation for incurring risk. A resource project is assessed to be profitable if the certainty equivalent value is non-negative (zero or positive). The valuation of the risk premium may therefore have an important influence on the assessment of project profitability.

An important feature of profit based royalties is that private investors share part of the risk of resource projects with governments. The extent of risk sharing depends on the design of the profit based royalty. A resource rent tax with full loss offset is similar to the Brown tax where the government is essentially a silent partner in the project (contributing the tax rate, for example 40 per cent, to the investment costs and receiving the tax rate applied to profits as a return on this investment). Under a resource rent tax, full loss offset is achieved when the net losses from failed resource projects are deductible against the profits from successful resource projects (this may occur through cash rebates, trade in losses between companies and/or companywide deductibility of losses).

The petroleum resource rent tax does not provide full loss offset. The system allows companywide deductibility of exploration expenditure – the risk of losses from failed exploration projects by new companies and failed development projects by all companies is accounted for, to some extent, by incorporating a risk premium in the fiscal settings (the threshold rate and/or the accelerated rate of deduction for different expenditure categories). A resource rent tax with less than full loss offset still provides significant risk sharing between the government and private investors since the resource rent tax is not triggered until private investors achieve the threshold rate of return. The government then collects a percentage (the tax rate) of annual profits in excess of the threshold return to private exploration and capital expenditure.

By contrast, under an ad valorem royalty, the government collects a constant percentage (the royalty rate) of the annual value of production irrespective of the net cash flow position of the project. In practice, the market price of the resource over the project life is a major source of risk for private investors. For each project, if production is assumed to be unchanged, the amount of revenue collected by the government under an ad valorem royalty will vary with the price outcome – reduced if the resource price is lower than expected and increased if the resource price is higher than expected. That is, the ad valorem royalty is responsive, at least to some extent, to changes in market price. However, the government receives royalty payments in all years in which production from the resource project is positive, including any years in which losses may unexpectedly occur.

Since the government collects ad valorem royalty payments in all possible outcomes where production is positive but project profitability may be significantly lower than expected, the risk premium for any given project tends to be increased under an ad valorem royalty (compared with the risk premium before the resource tax is applied).

The impact of the key policy options on the private investor's risk premium for the five hypothetical resource development projects (lower capital costs assumption) under price risk is illustrated in figure N. The risk premium is based on the mean

fig N **industry's risk premium under key policy options for each hypothetical resource project** lower capital costs
in present value terms

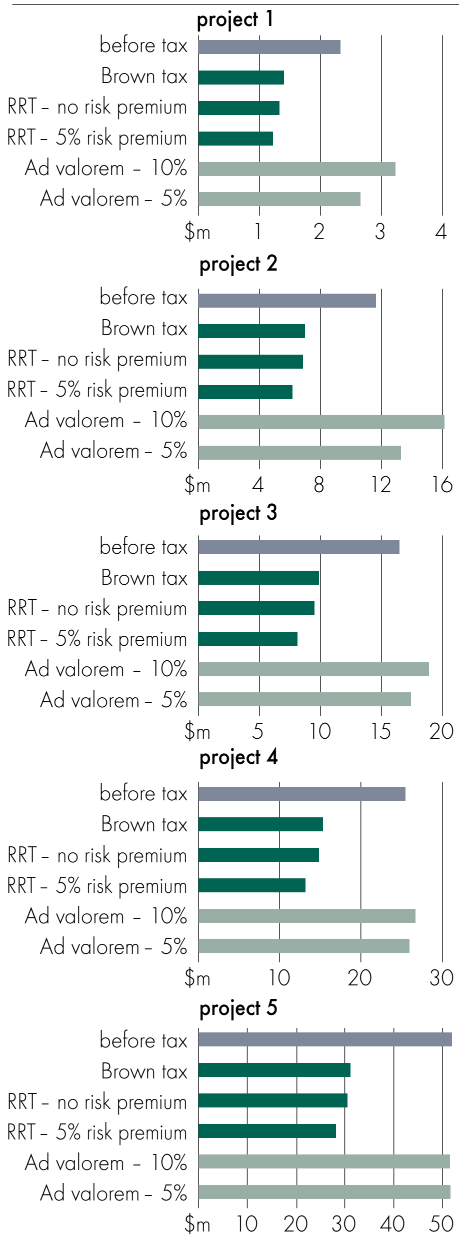
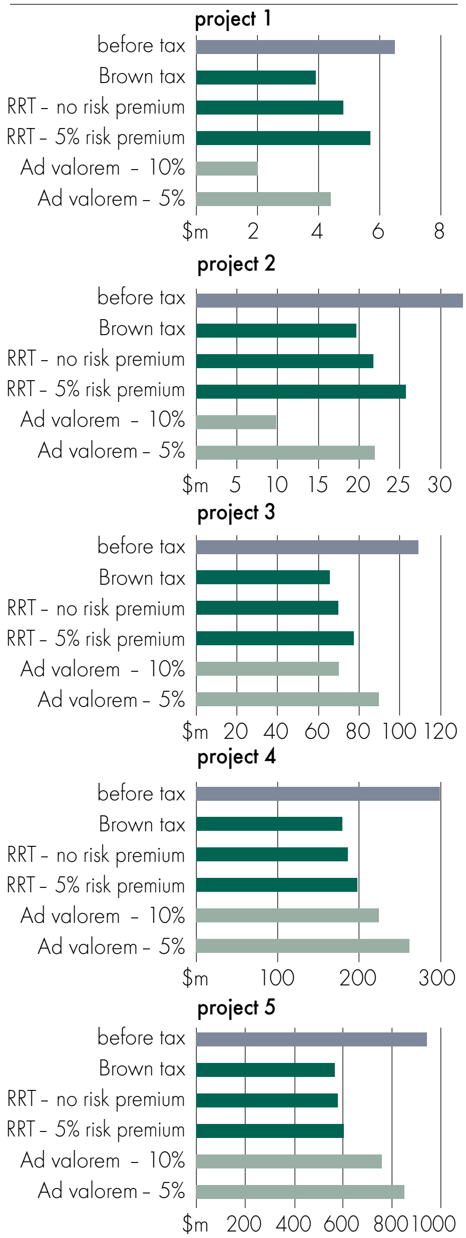


fig O **profitability assessment under key policy options for each hypothetical resource project** lower capital costs

certainty equivalent value; in present value terms



and variance of the distribution of possible outcomes for the project's net present value with a relatively standard assumption made with respect to the degree of risk aversion of the private investor (see chapter 4 for details).

The risk premium under each profit based royalty is consistently less than the risk premium before resource tax. By contrast, the risk premium tends to be increased under each ad valorem royalty – it is interesting to note that the risk premium is similar before and after the ad valorem royalty for the larger projects 4 and 5 indicating the relatively low government tax take has a negligible impact on the risk assessment of these highly profitable projects.

project profitability assessments

As indicated earlier, the profitability assessments of exploration and development projects are assumed to be based on the certainty equivalent value of each project. The certainty equivalent value is a measure of the risk adjusted return to private investors and is calculated as the expected net present value of the project (that is, the probability weighted sum of the net present values) less the risk premium.

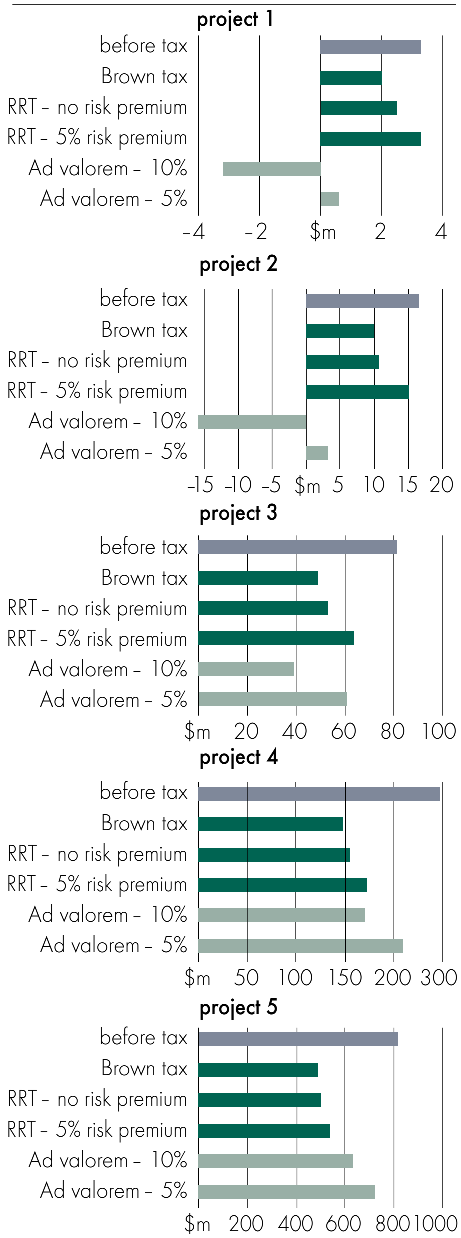
Under profit based royalties, the government tax take varies with project profitability and the risk premium is reduced compared with the before tax outcome (reflecting the risk sharing characteristics of profit based royalties).

Under an ad valorem royalty, the government tax take varies with the value of production (but not with project profitability) and the risk premium tends to be higher than the before tax outcome. There is some tendency for an ad valorem royalty to overtax low profit projects and undertax high profit projects.

Compared with the outcome under profit based royalties, the certainty equivalent value (CEV) under an ad valorem royalty tends to be higher for high profit projects (since these tend to be undertaxed) and lower for low profit projects (since these tend to be overtaxed). As a consequence, a resource project is more likely to switch from being economic before tax (CEV≥0) to uneconomic after tax (CEV<0) under an ad valorem royalty than under any of the profit based royalties.

The impact of the key policy options on the profitability assessments of the hypothetical resource development projects under price risk is illustrated in figures O and P corresponding to the assumptions of lower and higher capital costs, respectively. Each of the five hypothetical projects is profitable before any resource tax is applied (that is, the certainty equivalent value is positive before tax for each project). After resource tax, the

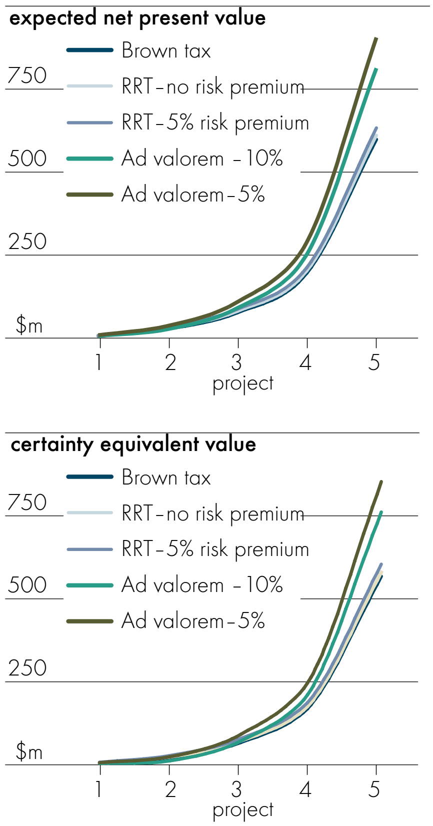
fig P **profitability assessment under key policy options for each hypothetical resource project** higher capital costs
certainty equivalent value; in present value terms



certainty equivalent value under the assumption of lower capital costs is the private investor's assessment of the profitability of each project after the government has collected resource royalty payments (see the government tax take in figure M) and after an appropriate adjustment for risk (see the risk premium in figure N).

Notably, the certainty equivalent value for projects 1 and 2 is lowest under the 10 per cent ad valorem royalty (around half the corresponding certainty equivalent value under the Brown tax) – while the government tax take is similar to the Brown tax outcome for these smaller projects, the risk premium under the 10 per cent ad valorem royalty is significantly higher than under the Brown tax.

fig Q **summary of profitability assessments under key policy options for hypothetical resource projects**
lower capital costs



For the larger projects 4 and 5, the certainty equivalent value is higher under the ad valorem royalties than under the profit based royalties, reflecting the relatively low government tax take under the ad valorem royalties.

The simulation results for the certainty equivalent value under the assumption of higher capital costs is included here to illustrate the negative distortions to private investment decisions that may occur under output based royalties (figure P). With higher capital costs, each of the five hypothetical resource development projects remains profitable before any resource tax is applied although project profitability is reduced (that is, the certainty equivalent value before tax for each project in figure P is positive but lower than the corresponding certainty equivalent value in figure O).

Notably, the certainty equivalent value is negative for projects 1 and 2 under the 10 per cent ad valorem royalty indicating these projects would switch from being assessed as profitable before tax to unprofitable after the 10 per cent ad valorem royalty is applied – projects 1 and 2 would not proceed under this policy option and the government tax take would be zero.

The certainty equivalent value for the larger projects 4 and 5 still tends to be higher under the ad valorem royalties than under the profit based royalties.

An overview of the expected net present value and certainty equivalent value for the hypothetical development projects (lower capital costs assumption) under the key policy options is presented in figure Q (the corresponding overview for the government tax take is provided in figure L).

future directions for resource taxation policy

By international and domestic standards, the Australian Government's petroleum resource rent tax is a competitive and efficient resource taxation system that enables the government, on behalf of the community, to collect a reasonable share of the resource rent. Over the past two decades, the Australian Government has gained extensive experience in administering this profit based royalty.

To assess the net economic benefits of extending a profit based royalty such as the petroleum resource rent tax to onshore mineral resources, the expected efficiency gains and the value of the resource rent collected through a mineral resource rent tax need to be compared with the likely increase in administrative costs. A significant advantage of a mineral resource rent tax designed along the lines of the petroleum resource rent tax is that it would be applied on a consistent basis to onshore mineral resources in Australia, replacing the current complex arrangements that have evolved over time across several jurisdictions.

resource royalty payments in Australia's mining sector

It is useful to examine resource royalty payments in Australia's mining sector to identify whether these payments are sufficiently important to merit consideration of major policy reform.

Resource royalty payments in Australia's mining sector are significant, although there is considerable industry variation (table 17). In 2002-03, resource royalty payments in Australia's mining sector were $4.5 billion (ABS 2004; note that this mainly comprises resource royalty payments, but also includes payments under mineral lease arrangements). Resource royalty payments are mainly sourced from the oil and gas extraction, coal mining and metal ore mining industries – $2.7 billion (or 58 per cent of the total) from oil and gas extraction in 2002-03, $1.0 billion (23 per cent) from coal mining, $0.7 billion (16 per cent) from metal ore mining and $0.1 billion (3 per cent) from nonmetal ore mining. Within the metal ore mining industry, iron ore mining (7.5 per cent) and gold ore mining (3 per cent) were the main sources of resource royalty payments in 2002–03.

Notably, the resource royalty payments from the nonmetal ore mining industry are likely to be sourced mainly from a relatively small number of resources and mine sites (for example, the Argyle diamond mine is an important resource project in this category – see also the ABS value of production data in appendix A for an indication of the relative importance of different nonmetallic mineral resources). Resource rent for many nonmetallic minerals (such as construction materials) may be insufficient to justify consideration of the introduction of a profit based royalty with its higher administrative costs. Instead, an option in this category may be to apply a mineral resources rent tax to specific nonmetallic resources (such as diamonds and gemstones) that are assessed to earn sufficient resource rent.

table 17 **resource royalty payments in Australia's mining sector, 2002-03** a

	resource royalty payments $m	share of total %
oil and gas extraction	2 651	58.3
coal mining	1 026	22.6
metal ore mining		
iron ore mining	340	7.5
gold ore mining	135	3.0
copper ore mining	50	1.1
silver–lead–zinc ore mining	42	0.9
mineral sand mining	27	0.6
other metal ore mining	127	2.8
total metal ore mining	722	15.9
nonmetal ore mining	137	3.0
total b	4 546	100.0

a Natural resource royalties expenses including payments under mineral lease arrangements, and resource rent taxes and royalties. **b** Includes services to mining.
Source: ABS (2004).

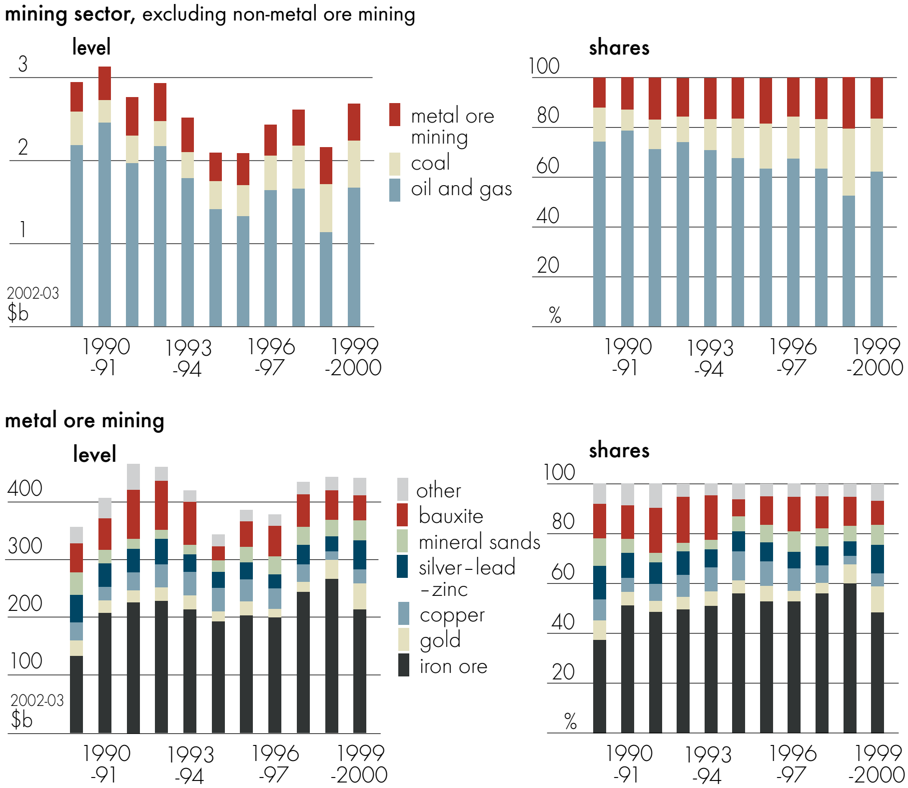
ABS data on resource royalty payments to governments in Australia are available for oil and gas extraction, coal mining and metal ore mining in the 1990s. The data are presented in figure R in real terms (in 2002-03 prices) – that is, resource royalty payments in nominal terms have been adjusted for annual inflation rates. Resource royalty payments to governments, in 2002-03 prices, fell by 9 per cent from $2.9 billion in 1989-90 to $2.6 billion in 1990-2000. Over the decade, real resource royalty payments fell by 24 per cent for oil and gas extraction, but increased by 41 per cent for coal ore mining and 24 per cent for metal ore mining.

Notably, there was a significant rationalisation of royalty arrangements for the coal mining industry during the decade, which is likely to have contributed to increased profitability in the industry and the rise in royalty payments (the current arrangements in New South Wales attempt to proxy a profit based royalty).

Oil and gas extraction was the major source of resource royalty payments during the decade, although its share of total payments from the mining sector (excluding nonmetal ore mining) fell from 74 per cent in 1989-90 to 62 per cent in 1999-2000. The royalty share for coal mining increased from 14 per cent in 1989-90 to 21 per cent in 1999-2000, and the royalty share for metal ore mining increased from 12 per cent in 1989-90 to 16 per cent in 1999-2000.

Apart from administrative simplicity, stability (or reduced uncertainty) in annual resource royalty payments has been a major reason given for the predominance in several jurisdictions for output based royalties. Reflecting the risk sharing characteristics

fig R **real resource royalty payments to governments in Australia**
in 2002-03 prices; based on ABS data



of profit based royalties, variability in annual resource royalty payments will be greater under profit based royalties than under output based royalties.

Notably, between 1989-90 and 1999-2000, the variability in annual resource royalty payments was relatively low for metal ore mining (the coefficient of variation is a measure of variability that is defined in chapter 4 – the coefficient of variation over the decade is 0.1 for metal ore mining, compared with 0.23 for oil and gas extraction and 0.28 for coal mining).

A major advantage of a profit based royalty over an output based royalty is that the former will result in efficiency gains that increase the resource rent or profitability from the mining activity (ignoring administrative costs). This is likely to result in higher resource royalty payments over time than would otherwise be the case.

industry profitability

ABS data for 2002-03 provide an indication of the return to industry from the extraction of Australia's mineral resources. Earnings before interest and company tax payments is a measure of accounting profit in the mining sector. Accounting profit includes a depreciation allowance for investment and hence may not be interpreted as a measure of net cash flow. Nevertheless, accounting profit should provide a useful indication of the return to the industry after resource royalty payments have been made.

table 18 **accounting profit in Australia's mining sector, 2002-03** a

	accounting profit $m	**share of total** %
oil and gas extraction	9 323	49.1
coal mining	4 022	21.2
metal ore mining		
iron ore mining	2 470	13.0
gold ore mining	753	4.0
copper ore mining	275	1.4
silver–lead–zinc ore mining	21	0.1
mineral sand mining	141	0.7
other metal ore mining	1 069	5.6
total metal ore mining	4 729	24.9
nonmetal ore mining	884	4.7
total b	18 995	100.0

a Earnings before interest and company tax. **b** Includes services to mining.
Source: ABS (2004).

In 2002-03, accounting profit was $19.0 billion in Australia's mining sector – $9.3 billion in oil and gas extraction, $4.0 billion in the coal mining industry, $4.7 billion in the metal ore mining industry and $0.9 billion in the nonmetal ore mining industry (table 18). It may be noted that the distribution of accounting profit across mining industries differs slightly from the distribution of resource royalty payments across mining industries (as given in table 17) – the profit shares are lower for oil and gas extraction (49 per cent) and the coal mining industry (21 per cent), and higher for the metal ore mining industry (25 per cent) and the nonmetal ore mining industry (5 per cent).

Mining tends to be a highly capital intensive activity, with substantial investment required in the development stage of resource projects. It is useful to consider two further measures of industry profitability that provide an indication of the return on private investment expenditures – these are the return on funds and the return on assets (table 19).

table 19 **industry profitability in Australia's mining sector, 2002-03**

	return on funds a	return on assets b
	%	%
oil and gas extraction	22.0	18.2
coal mining	20.9	14.6
metal ore mining		
iron ore mining	26.7	19.7
gold ore mining	8.2	5.1
copper ore mining	5.9	3.0
silver–lead–zinc ore mining	1.1	–4.6
mineral sand mining	7.8	3.4
other metal ore mining	42.5	20.8
total metal ore mining	16.1	9.7
nonmetal ore mining	16.0	11.0
total	18.6	13.3

a Earnings before interest and tax (EBIT) as a percentage of the sum of shareholders' funds and non-current liabilities. **b** Operating profit before tax as a percentage of the total book value of assets. *Source*: ABS (2004).

The return on funds is accounting profit as a percentage of funds (representing equity and debt financing of the investment expenditures). In 2002-03, the return on funds was around 19 per cent in the mining sector – 22 per cent in oil and gas extraction, 21 per cent in coal mining, and 16 per cent in both metal ore mining and nonmetal ore mining. There was considerable variation in the return on funds for individual metal ore mining industries, ranging from 27 per cent in iron ore mining to 1 per cent for silver–lead–zinc ore mining.

The return on assets is accounting profit less interest payments (also referred to as operating profit before company tax) as a percentage of the total book value of assets. In 2002-03, the return on assets was 13 per cent in the mining sector – 18 per cent in oil and gas extraction, 15 per cent in coal mining, 10 per cent in metal ore mining and 11 per cent in nonmetal ore mining (table 19). Within the metal ore mining industry, the return on assets ranged from 20 per cent in iron ore mining to –5 per cent for silver–lead–zinc ore mining.

distribution of mining profit to industry and government

It should be emphasised that an important efficiency aspect of a profit based royalty is that resource royalty payments will vary with project profitability and hence industry profitability. Clearly, from the information presented above on three profitability measures, the return to industry varies significantly between mining industries.

It is useful to examine the distribution of mining profit to industry and government to provide an indication of the extent to which resource royalty payments vary with industry profitability. Mining profit refers to accounting profit before resource royalty payments are made – that is, mining profit is equal to resource royalty payments (see table 17) plus accounting profit (see table 18).

In 2002-03, resource royalty payments accounted for 19 per cent of mining profit in Australia's mining sector, with the remaining 81 per cent representing the return to industry (table 20). The share of resource royalty payments in mining profit ranged from 22 per cent for oil and gas extraction and 20 per cent for coal mining to 13 per cent for both metal ore mining and nonmetal ore mining.

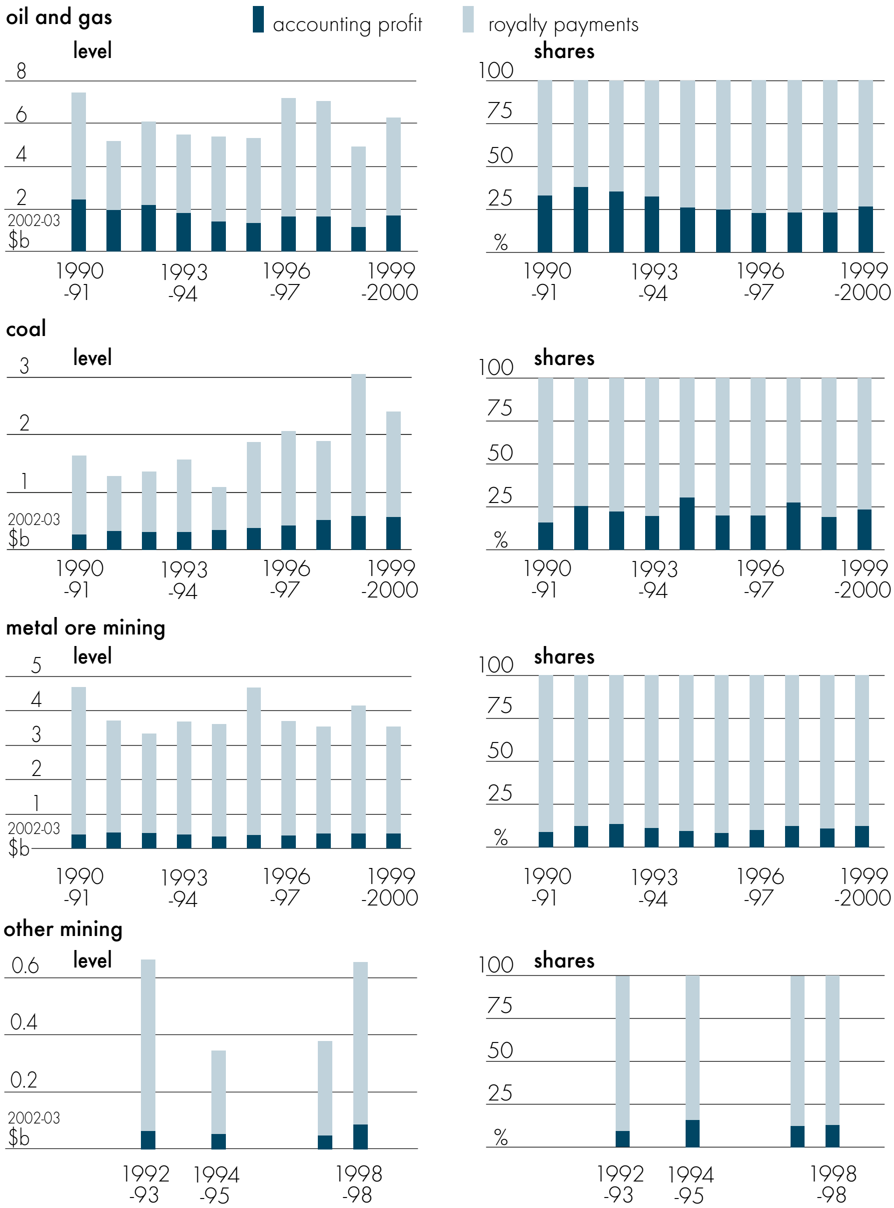
Notably, 67 per cent of mining profit in the silver–lead–zinc ore mining industry was collected by the government through resource royalty payments – this may highlight the lack of responsiveness of output based royalties to annual variation in project profitability.

table 20 **distribution of mining profit to industry and governments in Australia, 2002-03**

		share of mining profit to:	
	mining profit a	**governments** b	**industry** c
	$m	%	%
oil and gas extraction	11 974	22.1	77.9
coal mining	5 048	20.3	79.7
metal ore mining			
iron ore mining	2 809	12.1	87.9
gold ore mining	888	15.2	84.8
copper ore mining	325	15.5	84.5
silver-lead-zinc ore mining	63	66.9	33.1
mineral sand mining	169	16.2	83.8
other metal ore mining	1 197	10.6	89.4
total metal ore mining	5 451	13.2	86.8
nonmetal ore mining	1 020	13.4	86.6
total d	23 541	19.3	80.7

a Equal to resource royalty payments plus accounting profit. **b** Resource royalty payments as a percentage of mining profit. **c** Accounting profit as a percentage of mining profit. **d** Includes services to mining.
Source: ABS (2004).

fig S **distribution of mining profit to industry and governments in Australia**
in 2002-03 prices; based on ABS data



In figure S, the ABS data on resource royalty payments to governments in the 1990s are compared with accounting profit for the four major mining industries. Data for resource royalty payments to governments in the nonmetal ore mining industry are incomplete.

Consistent with the general observations for 2002-03, the government shares of mining profit are higher on average for the oil and gas extraction and coal mining industries than in the metal ore mining and nonmetal ore mining industries. Between 1989-90 and 1999-00, on average, resource royalty payments to governments accounted for 19 per cent of mining profit in Australia's mining sector – 24 per cent for oil and gas extraction, 22 per cent for coal mining, 11 per cent for metal ore mining and 13 per cent for nonmetal ore mining (the lattermost is the average over the four years included in figure S).

The share of mining profit collected by governments appears to be significantly lower in the metal ore mining and nonmetal ore mining industries where output based royalties generally apply. (It may be noted that different ad valorem royalty rates apply to different segments of the New South Wales coal industry based broadly on cost structures.) This may indicate that governments have been willing to collect overall a smaller share of the resource rent in the metal ore mining and nonmetal ore mining industries to reduce the negative impact of output based royalties on marginal or low profit resource projects in these industries.

diversity in resource projects

The potential efficiency gains from extending a profit based royalty such as the petroleum resource rent tax to onshore mineral resources in Australia will be influenced by the extent to which the quality of mineral resource deposits, and hence project profitability, varies (this influences the upward slope in the long run marginal cost curve in figure B). The greater the diversity of resource projects in Australia, the greater the potential efficiency gains from extending the profit based royalty to onshore mineral resources.

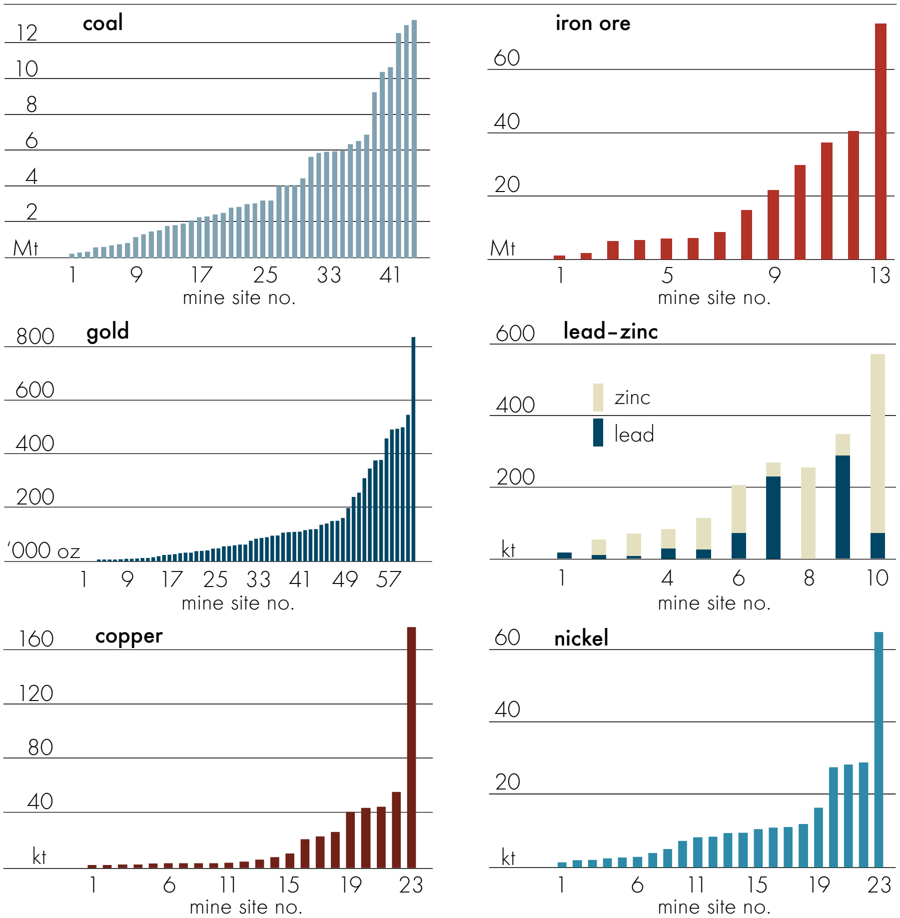
Information on the net cash flow of individual resource projects in Australia is not publicly available. However, production data from Minmet (2006) provide an indication of the diversity in resource projects. Production at mine sites in Australia for selected major mineral resources in 2005 is presented in figure T. The selected mineral resources are coal, iron ore, gold, lead–zinc, copper and nickel.

Each of these resources is significant in Australia's exports (ABARE 2006a). In 2005-06, the total value of mineral resources exports was $92 billion – exports were

$24 billion (26 per cent of total mineral resources exports) for coal and, including metals, $15 billion (16 per cent) for iron ore and steel, $7 billion for gold (although part of this represents the reprocessing of imported gold), $4 billion (4 per cent) for lead–zinc, $6 billion for copper (6 per cent) and $4 billion for nickel (4 per cent).

In figure T, mine sites are ranked by production in 2005 with the exception of lead-zinc which is ranked according to the value of production (the price of zinc is significantly higher than the price of lead; see ABARE 2006a). Lead and zinc production by mine site is presented together since joint production is particularly

fig T **production at mine sites in Australia for selected resources, 2005**
based on Minmet data



important for these resources. Several mine sites produce more than a single mineral resource – for example, some mines produce both gold and copper, and copper and/or cobalt are produced at some nickel mines.

The information presented in figure T is therefore a simplified representation of production at mine sites in Australia. The key observation is that there is substantial diversity in mine production for these mineral resources. With economies of scale, unit profit (or profit per unit of production) would be higher at mine sites with larger production (all else constant). Other influences on project profitability include, for example, the ore grade, quality characteristics of the resource (for example, the sulphur and ash content in coal, and impurities more generally), and geographic location of the mine site (for example, mine sites in mature mineral producing areas such as the Eastern goldfields in Western Australia and Mount Isa in Queensland would tend to have better access to transport and other infrastructure than mine sites in remote areas).

The extent to which there is diversity in resource projects in Australia provides an indication of the difficulties facing policy makers in assessing the tradeoff between overtaxing low profit projects and undertaxing high profit projects under output based royalties.

concluding comments

The petroleum resource rent tax is an efficient resource taxation system that has enabled the Australian Government, on behalf of the community, to collect a reasonable share of the resource rent in areas where this arrangement applies. The resource rent is the return to the petroleum resource. The key fiscal settings in the petroleum resource rent tax are the 40 per cent tax rate, the 5 per cent risk premium in the threshold rate for general project expenditures and companywide deductibility of exploration expenditures.

The increased risks for offshore oil and gas exploration in specified frontier areas is recognised in the 150 per cent tax deduction allowed for these expenditures. For new companies, the increased risks associated with the lack of immediate deductibility for exploration expenditures is recognised through an additional risk premium in the threshold rate that applies for these companies.

Significant information on the net cash flow of resource projects is required to administer the petroleum resource rent tax. Extending a profit based royalty such as the petroleum resource rent tax to onshore mineral resources would involve significant transitional costs and increase the information requirements for administering resource taxation arrangements in Australia. There are also likely to be a number of issues that would need to be resolved in replacing the current systems that apply across several jurisdictions with a consistent mineral resource rent tax – for example, the taxation treatment of failed exploration projects would need to be considered (companywide deductibility of exploration expenditures is an important component of the petroleum resource rent tax).

The Australian Government has considerable expertise in both implementing major resource taxation policy reform and administering the petroleum resource rent tax. The petroleum resource rent tax was introduced in 1987 and subsequently modified on a number of occasions to improve the efficiency of the system, providing the Australian Government with twenty years experience in administering this system. Importantly, the petroleum resource rent tax was extended to the Bass Strait project in 1990, providing the Australian Government with direct experience in replacing an output based royalty regime with a profit based royalty regime.

Overall, in assessing the merits of extending a profit based royalty such as the petroleum resource rent tax to onshore mineral resources in Australia, there are a number of issues that should be considered by governments in Australia:

- *Government tax take* – under a profit based royalty, governments would aim to collect a reasonable share (for example, 40 per cent) of project profits in excess of a threshold rate of return. A profit based royalty is more likely to collect a reasonable share of the industry's resource rent since the current system of output based royalties tends to overtax low profit projects and undertax high profit projects.
- *Efficiency implications of the resource taxation policy* – there is the potential for significant efficiency gains under this profit based royalty since royalty payments would only be made when the project has earned profits in excess of a threshold rate of return. Resource rent is likely to be higher under a profit based royalty than under an output based royalty.
- *Administrative costs* – a consistently applied profit based royalty may result in higher administrative costs due to the greater information requirements of this arrangement, but sovereign risk may be reduced and the need for ongoing assessments of (and adjustments to) ad valorem and specific royalty rates in the current complex set of arrangements would be avoided.
- *Transitional costs* – the costs of implementing the policy change may be significant, although the Australian Government has direct experience in this area with the extension of the petroleum resource rent tax to Bass Strait in 1990.

The government tax take and the efficiency implications of the resource taxation policy will be influenced by the size and distribution of project profits both within a time period as well as over time. The greater the diversity of resource projects in Australia, the greater the potential efficiency gains, and increase in resource rent, from extending the profit based royalty to onshore mineral resources.

Given Australia's substantial mineral resource assets, it is likely that there would be significant net economic benefits in extending a profit based royalty such as the petroleum resource rent tax to onshore mineral resources. The possible exception to this arrangement may be low value high volume nonmetallic minerals – apart from selected nonmetallic minerals such as diamonds and gemstones, resource rent in the nonmetal ore mining industry may be insufficient to justify the introduction of a profit based royalty with its higher administrative costs. Importantly, given its extensive experience in administering the petroleum resource rent tax, the Australian Government is well positioned to make a judgment about the expected administrative and transitional costs associated with extending a profit based royalty to onshore mineral resources in Australia.

ABS value of mineral production

ABS estimates of the value of mineral production provide a useful indication of the relative importance of a wide range of mineral resources in different jurisdictions in Australia. In this appendix, detailed data for 2002-03 are provided based on ABS (2004), although the qualifications given by ABS should be noted.

table 21 **value of mineral production in Australia, by mineral resource and jurisdiction, 2002-03** based on ABS data

	WA	Qld	NSW	Vic	NT	SA	Tas	Australia
	$m	$m	$m	$m	$m	$m	$m	$m
oil and gas								
crude oil	4 296	79	–	2 068	1 272	145	–	7 861
natural gas	667	381	–	696	45	346	–	2 135
natural gas condensate	2 052	72	–	na	–	88	–	2 212
other derivatives – ethane	–	–	–	–	–	3	–	3
liquefied petroleum gas (LPG)								
– propane	172	36	–	na	–	78	–	286
– butane	222	24	–	na	–	38	–	283
– total LPG	394	59	–	529	–	116	–	1 098
methane gas	–	na	2	–	–	–	–	2
liquefied natural gas (LNG)	3 132	–	–	–	–	–	–	3 132
total oil and gas	10 542	592	2	3 294	1 317	697	0	16 444
coal								
salable black coal – type	273	7 452	4 953	0	0	46	0	12 723
– bituminous	–	6 352	4 953	–	–	–	na	11 305
– semi-anthracite	–	554	–	–	–	–	–	554
– sub-bituminous	273	546	–	–	–	46	–	865
salable black coal – source								
– underground	–	na	na	–	–	–	na	0
– opencut	na	na	na	–	–	na	–	0
black coal washery rejects	.	.	.	.	.	.	.	0
brown coal	0	0.1	0	535	0	0	0	535
– brown coal (lignite)	–	–	–	535	–	–	–	535
– peat	–	0.1	–	–	–	–	–	0
total coal	273	7 452	4 953	535	0	46	0	13 258

continued...

table 21 **value of mineral production in Australia, by mineral resource and jurisdiction, 2002-03** based on ABS data *continued*

	WA	Qld	NSW	Vic	NT	SA	Tas	Australia
	$m	$m	$m	$m	$m	$m	$m	$m
metallic minerals								
bauxite (including calcined and beneficiated)	na	212	–	–	152	–	–	363
copper								
– copper concentrate	66	1 246	389	–	–	477	91	2 269
– copper precipitate	–	120	–	–	–	–	–	120
gold								
– gold bullion (doré)	3 444	294	482	61	352	65	99	4 798
iron ore								
– iron ore and concentrate	5 194	–	–	–	–	26	3	5 223
– iron oxide								
• for coal washing (magnetite)	–	–	5	–	–	–	7	11
• for other purposes (eg. paint manufacture)	–	–	–	–	–	–	–	0
– iron ore pellets (gross weight)	–	–	–	–	–	na	104	104
mineral sands								
– synthetic rutile/ beneficiated ilmenite	353	–	–	–	–	–	–	353
– ilmenite concentrate	137	na	–	na	–	–	–	137
– leucoxene concentrate	16	–	–	–	–	–	–	16
– rutile concentrate	83	na	5	na	–	–	–	87
– zircon concentrate	259	–	4	na	–	–	–	262
– total mineral sands	847	69	8	na	–	–	–	924
nickel								
– nickel concentrate	1 972	–	–	–	–	–	–	1 972
silver–lead–zinc								
– lead concentrate	31	772	81	–	–	–	21	906
– zinc concentrate	173	826	313	–	–	–	50	1 362
– zinc ore	–	–	–	–	–	0.2	–	0.2
– silver concentrate	–	–	22	–	0.5	5	–	27
– zinc–lead concentrate	–	–	–	–	106	–	–	106
tin–tantalum–lithium								
– tin concentrate	–	–	6	–	–	–	30	36
– tantalite-columbite concentrate	216	–	–	–	–	–	–	216
– lithium ores (petalite, amblygonite, spodumene)	na	–	–	–	–	–	–	0
metallic minerals nec								
– antimony concentrate	–	–	–	–	–	–	–	0

continued...

table 21 **value of mineral production in Australia, by mineral resource and jurisdiction, 2002-03** based on ABS data *continued*

	WA	Qld	NSW	Vic	NT	SA	Tas	Australia
	$m	$m	$m	$m	$m	$m	$m	$m
– chromite ore (Cr_2O_3 content)	6	–	–	–	–	–	–	6
– manganese ore/ manganese fines	–	–	–	–	199	–	–	199
– metallurgical grade greater than 48% manganese	75	–	–	–	–	–	–	75
– uranium concentrate (U_3O_8)	–	–	–	–	154	153	–	308
– other metallic minerals	17	–	–	–	–	–	–	17
total metallic minerals	12 042	3 539	1 307	61	963	726	405	19 043
nonmetallic minerals – construction materials								
sand and gravel								
– sand								
• for concrete	na	na	na	67	na	13	1.5	82
• for other purposes	na	na	na	16	na	15	1.5	32
• total sand	7	na	101	83	2	28	3	225
– gravel	1.1	na	77	32	4	0.5	0.2	114
crushed and broken stone								
– basalt	na	na	na	152	na	3	8	163
– dacite, rhyodacite, rhyolite and toscanite	na	na	na	17	na	–	–	17
– dolerite	na	na	na	5	na	–	10	14
– dolomite	na	na	na	–	na	–	0.3	0.3
– gneiss	na	na	na	0.1	na	–	–	0.1
– granite	na	na	na	33	na	4	–	37
– hornfels	na	na	na	45	na	–	–	45
– limestone	na	na	na	5	na	–	0.4	6
– quartzite	na	na	na	1.1	na	–	–	1.1
– sandstone	na	na	na	–	na	–	–	0.0
– other crushed and broken stone	na	na	na	8	na	29	1	39
– total crushed and broken stone	8	na	186	266	22	37	19	538
dimension stone								
– basalt	–	–	–	na	na	–	–	0.0
– granite	0.2	–	0.7	na	na	1.2	–	2.1
– limestone	–	–	–	–	na	0.3	–	0.3
– sandstone	–	9	4	na	na	0.1	0.1	13
– other dimension stone (incl. slate)	0.2	0.6	–	0.2	na	3	–	4
– total dimension stone	0.4	10	5	1.2	0.1	5	0.1	21

continued...

table 21 **value of mineral production in Australia, by mineral resource and jurisdiction, 2002-03** based on ABS data *continued*

	WA	Qld	NSW	Vic	NT	SA	Tas	Australia
	$m	$m	$m	$m	$m	$m	$m	$m
other construction materials (decomposed rock, etc.)								
– earth and soil	na	na	na	0.2	0.5	–	na	0.7
– filling	na	na	na	–	–	6	na	6
– scoria	na	na	na	8	–	–	na	8
– shale	na	na	na	–	–	1.1	na	1.1
– tuff	na	na	na	3	–	–	na	3
– construction materials nec (incl. shell grit and decomposed rock)	na	na	na	–	–	44	na	44
– total other construction materials	na	na	29	11	0.5	52	5	98
total construction materials	17	360	399	393	28	122	27	1345
other nonmetallic minerals								
limestone (incl. shell and coral) for:								
– agriculture	na	na	na	9	na	1.1	na	10
– burning	na	–	na	–	na	–	na	0
– cement	na	na	na	4	na	14	na	19
– chemicals	na	–	na	–	na	13	na	13
– flux (incl. in metal industries)	na	na	na	–	na	–	na	0
– other purposes	na	na	na	8	na	0.7	na	9
– total limestone	18	58	32	21	na	30	na	158
clays								
– bentonite	–	11	2	–	–	–	–	13
– brick clay and shale	–	3	13	3	–	1.3	0.1	21
– cement clay and shale	–	1.3	–	–	–	0.1	0.3	1.7
– fireclay nec	–	–	–	–	–	0.5	–	0.5
– kaolin (incl. ball clay)	0.1	0.9	1.1	na	–	0.1	–	2.2
– pipe and tile clay (incl. terracotta for roofing tiles)	–	–	na	0.2	–	–	–	0.2
– pottery clay (incl. moulder's clay)	–	–	–	–	–	0.8	–	0.8
– stoneware clay	–	–	–	–	–	–	–	0.0
– other clays	1.4	–	–	na	–	1.1	–	2.5
gems (precious stones)								
– chrysoprase	–	–	–	–	na	–	–	0.0
– diamonds	771	–	–	–	14	–	–	785
– opal	–	0.5	35	–	na	36	–	71.4
– rhodonite	–	–	–	–	na	–	–	0.0
– sapphire	–	1.1	1.9	–	na	–	–	3.0
– zircon	–	–	–	–	na	–	–	0.0
– gems nec	0.2	0.1	–	–	na	–	0.1	0.4

continued...

table 21 **value of mineral production in Australia, by mineral resource and jurisdiction, 2002-03** based on ABS data *continued*

	WA	Qld	NSW	Vic	NT	SA	Tas	Australia
	$m	$m	$m	$m	$m	$m	$m	$m
other nonmetallic minerals								
– barite	–	–	–	–	0.4	0.8	–	1.2
– diatomite (diatomaceous earth)	–	1.2	3	–	–	–	–	4
– dolomite	0.1	1.3	0.8	–	–	9	–	11
– feldspar (incl. cornish stone)	2	–	–	na	–	–	–	2
– garnet concentrate	na	–	–	–	–	–	–	0
– gypsum	20	1.9	2	na	–	5	–	30
– magnesite, crude	–	17	1.0	–	–	–	–	18
– mica	–	–	–	–	–	–	–	0.0
– perlite	–	1.8	–	–	–	–	–	1.8
– phosphate rock	–	131	–	–	–	–	–	131
– pyrophyllite	–	–	–	–	–	–	–	0
– salt (incl. solar salt)	228	27	–	–	–	6	–	260
– silica for industrial purposes								
• glass	na	na	na	–	–	na	1.7	1.7
• flux	na	–	na	–	–	na	–	0.0
• foundries	na	na	na	0.3	–	1.0	–	1.3
• other purposes	na	na	1.9	0.1	–	na	1.1	3
• total silica	8	27	11	0.4	–	2.2	3	51
– sillimanite	–	–	–	–	–	–	–	0
– talc (incl. steatite)	15	–	–	–	–	0.1	–	15
– vermiculite	–	–	–	–	5	–	–	5
– nonmetallic minerals nec	1.7	–	1.9	–	–	–	–	4
total other nonmetallic minerals	1 066	283	105	25	20	92	41	1 631
total nonmetallic minerals	1 082	644	503	418	48	213	69	2 977
total mineral resources	23 939	12 227	6 765	4 307	2 328	1 682	473	51 722

nec Not elswhere classified.
Source: ABS (2004).

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