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**The State of Resource Taxation in
Australia: “An Inexcusable
Folly for the Nation”?***

by

Rob Fraser

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INTRODUCTION

This quote is taken from a powerful critique by Craig Emerson and Peter Lloyd of the Australian resource taxation system published in the *Economic Record* in 1983. This was also the year of first election of the Hawke Labour government, an Australian Federal government which made a determined effort, largely unsuccessfully in my view, to address the concerns with this system described in Emerson and Lloyd.¹

These concerns were of two main types:

- (i) the base used to tax resources was typically either volume or value (specific or ad valorem), both of which were seen to be inferior relative to the “optimal” base of economic profit identified by the academic contributions of Garnaut and Clunies-Ross (1975, 1979) and Leland (1978).²
- (ii) the essentially state-based system of resource taxation was seen to be vulnerable to disharmony in the treatment of individual resources, and competition among the states in attracting resource development.

The Hawke government’s attempt to deal with the second type of concern centred on a unification of the system of resource taxation at the Federal level, and failed. This only left it the Australian territorial waters as a domain for improving the tax base and, in connection with this, the Petroleum Resource Rent Tax (PRRT) was introduced in 1987. This tax is essentially an operational form of the Resource Rent Tax (RRT) proposed by Garnaut and Clunies-Ross.

In this address I will be focusing on the claims made for the RRT by Garnaut and Clunies-Ross, including an empirical assessment of the performance of the PRRT relative to other forms of resource taxation. In so doing, I will be attempting to answer the question posed in the title.

The structure of my address is as follows. In the first section I will outline the essential features of the RRT, including a brief discussion of the two principle claims for the RRT made by Garnaut and Clunies-Ross. Specifically that:

- (i) it “appears to do less to reduce efficiency in the use of resources than alternative taxation systems” (1975, p272) and
- (ii) it “can secure for the government a higher proportion of supernormal profits from each resource than most other taxation systems” (1975, p272).

In addition, I will discuss one of Garnaut and Clunies-Ross’ principle caveats to the superiority of the RRT, that “the greater expected revenue would be achieved at the expense of greater uncertainty about receipts” (1975, p282).

In subsequent sections I will examine each of these issues in greater detail. In the second section I examine the issue of whether other forms of resource taxation, such as the commonly-used ad valorem royalty, do actually have “a disincentive effect on production” (Emerson and Lloyd, 1983, p240). Drawing on Fraser and Rognestad (1999), I will argue that in certain circumstances, and in particular where trade is best characterised by a form of bilateral monopoly, ad valorem royalties are unlikely to be a disincentive to production, and may in fact be a stimulus. Consequently, in these circumstances, there is no efficiency argument to favour the RRT over a typical royalty system. In the third section I consider both the second claim of Garnaut and Clunies-Ross regarding the superiority of the RRT in terms

of expected tax revenue, and their caveat to this superiority regarding the greater uncertainty of such revenue. In particular, I explore the evidence to date regarding the performance not just of the PRRT, but also of the Resource Rent Royalty (RRR) jointly applied by the Western Australian (WA) and Australian governments to Barrow Island petroleum since 1985, relative to the ad valorem royalty system applied to petroleum from the North-West Shelf (NWS).³ This exploration will support the conjectures of Garnaut and Clunies-Ross, and so in the fourth section I consider whether the risk-return trade-off associated with a shift from ad valorem taxation to an RRT is worthwhile. My analysis in this section supports the view that the trade-off is worthwhile, and in so doing I provide estimates of the magnitude of our nation's "inexcusable folly" in relation to resource taxation.

The final section of the address turns to what is in my view the most justifiable concern with the adoption of the RRT form of resource taxation: its vulnerability to rorting. Here I make use of the literature of the economics of regulation to draw parallels (first identified by Garnaut and Clunies-Ross, 1979) between the RRT and rate-of-return regulation. In so doing, I will focus on the major weakness in rate-of-return regulation which inspired the development of the now-popular price-cap regulation, and suggest a means of modifying the RRT so that it captures for this resource taxation system the essential strength of the innovation represented by price-cap regulation.

SECTION 1: Essential Features of the RRT

The essential features of the RRT as developed by Garnaut and Clunies-Ross are:

- (i) a focus on profits by allowing certain costs to be deducted from revenues in determining tax liability
- (ii) a threshold rate-of-return on capital as a component of allowable cost deductions
- (iii) a marginal rate of tax which applies to profits in excess of those consistent with the allowable rate-of-return on capital.

Drawing on Fraser (1993), no tax is payable if:

$$(px - ck)/k < r \quad (1)$$

where: p = price per unit of extracted resource
 x = units of extracted resource
 c = operating costs per unit of capital
 k = units of capital
 r = threshold rate of return.

But if:

$$(px - ck)/k > r \quad (2)$$

then tax paid is given by:

$$t(px - (c + r)k). \quad (3)$$

On this basis, profit in the presence of the RRT is given by:

$$\begin{aligned} \pi &= px - ck & \text{if } (px - ck)/k \leq r \\ \pi &= px - ck - t(px - (c + r)k) & \text{if } (px - ck)/k > r. \end{aligned} \quad (4)$$

This profit function is clearly kinked at the level r_k . Moreover, as demonstrated in Fraser (1999b), when compared with an ad valorem royalty designed to yield the same level of expected tax revenue, the distorting impact on production of the RRT is unambiguously smaller than that of the ad valorem royalty. This feature of appearing “to do less to reduce efficiency” can be traced to the kink, insofar as the firm’s profit function below the kink is completely unaffected by the presence of the tax, unlike the case of the ad valorem royalty which reduces all feasible profit outcomes (see Figure 1).⁴ And in fact, depending on the specification of the firm’s economic circumstances, the RRT can be shown to have two separate positive impacts on the optimal production decision. The first of these, analysed in Fraser (1993) following its identification in Garnaut and Clunies-Ross (1979), stems from the opportunity to decrease the likelihood of having to pay tax by increasing the level of optimal investment, and thereby decreasing all feasible rates-of-return. This is the version of the Averch-Johnson effect which applies to the RRT (Averch and Johnson, 1962). The second, analysed in Fraser (1998) but also identified in Garnaut and Clunies-Ross (1975), stems from the risk-sharing quality of the RRT, by which means some of the riskiness of profit outcomes is transferred to the government to take the form of variability of tax revenues. For a risk averse firm, this transfer of risk has a positive impact on its production decision.

Moreover, there is no need for a government simply to accept the relative superiority of the RRT in terms of its distorting effect on production. If preferred, it can “trade” some of this superiority for “a higher proportion of super-normal profits”. As shown in Fraser and Kingwell (1997), a simulated comparison of the RRT with ad valorem royalties in the context of investment-neutrality shows an unambiguous and in many cases substantial superiority for the RRT in terms of the level of expected tax revenue. Consequently, we argue that concern over the expected tax benefits from converting an ad valorem royalty system to the RRT

cannot be used to explain the reluctance of state governments in Australia to adopt the RRT form of resource taxation.⁵

However, Garnaut and Clunies-Ross (1975) did suggest that “the greater expected revenue would be achieved at the expense of greater uncertainty about receipts”, and so it may be the existence of this trade-off which is inhibiting the adoption of the RRT form by state governments. In Fraser (1999b) I explore this issue in the context of the Western Australia gold royalty. Based on simulations comparing the variability of tax revenues from an ad valorem royalty system and an RRT system, and using the concept of tax revenue-neutrality as a benchmark, I show that the coefficient of variation of tax revenue varies from about 30% for the ad valorem royalty, to over 80% for the RRT.⁶

On the basis of this research, the first question in my mind is whether such differences which arise in simulated situations also manifest themselves in the actual performance of the operational forms of the two tax systems. And, on the basis of estimates of the risk-return trade-off associated with changing tax systems, the second question is whether this trade-off is worthwhile. As stated in the Introduction, I address these issues in Sections 3 and 4 respectively, after first addressing in more detail the issue of the distorting effect of royalties in Section 2.

SECTION 2: The Disincentive Effect of Royalties

The previous discussion, and the resource taxation literature in general, has supported the view that (ad valorem and specific) royalties are an inferior form of resource taxation partly because of their disincentive effect on production. In this section I summarise briefly the argument of Fraser and Rygnestad (1999) which endeavours to qualify this view. In particular, we argue that in a trading situation best characterised by the bilateral monopoly model, the imposition of royalties may actually increase the quantities of resource traded. Since it has been suggested by Smith (1977), Bowen and Gooday (1993) and Chang and Sheales (1993) that such a characterisation can be applied to the trading situation between Australian and Japan for coal and iron ore, and since coal and iron ore are both subject to royalty regimes and are two of Australia's four largest export earners (1997-98: coal approximately \$9b; iron ore approximately \$4b), this argument would appear to be of some significance.⁷

In this context, consider Figures 2 and 3 which reproduce Figures 3 and 4 respectively of Fraser and Rygnestad (1999). These figures represent two distinct forms of the bilateral monopoly model. In the case of Form 1 (Figure 2), the seller's marginal cost function (mcf) and its associated marginal factor cost function (mfcf) rise relatively sharply (in the region of the bargain). As a consequence, the preferred position of the seller in the absence of royalties (B) is characterised by a higher price and a higher quantity relative to that of the buyer (A). Moreover, the line \overline{AB} , which is used as a simplification to represent the set of feasible outcomes of the bargaining process, is positively sloped. By contrast, in the case of Form 2 (Figure 3), the mcf (and its associated mfcf) rise relatively slowly. As a consequence, the preferred position of the seller (Y) is characterised by a higher price and a lower quantity

relative to that of the buyer (X), and the line \overline{XY} is negatively sloped. Note that, in the absence of royalties, the outcome of the bargaining process in each case has been specified as the mid-point of the lines of feasible outcomes: M in the case of Form 1; and W in the case of Form 2.

Now consider the impact of the imposition of royalties. In each case this causes a downward shift in the marginal revenue curve of the seller (from MR to MR_R), which shifts the preferred position of the seller further up the demand curve (to B_R for Form 1 and Y_R for Form 2), and thereby rotates anti-clockwise the lines of feasible outcomes (to \overline{AB}_R for Form 1 and \overline{XY}_R for Form 2). In the absence of any change in the relative bargaining power of the buyer and the seller, the new positions of agreement would be represented by M_R in the case of Form 1, and W_R in the case of Form 2. However, the argument made in Fraser and Rystad (1999) is that the imposition of a royalty will modify the relative bargaining power of the buyer and the seller. In particular, it is suggested that “the new requirement for the seller to bear the financial burden of royalty payments will weaken its financial position and therefore weaken its bargaining power” (p4). Accepting this argument implies a new position of agreement which is closer to the preferred position of the buyer (A in the case of Form 1 and X in the case of Form 2). For illustrative purposes these new positions have been represented as N and Z in Figures 2 and 3 respectively. In the case of Form 1 it can be seen that taking account of the impact of the royalty on relative bargaining power serves to reinforce the initial tendency for the royalty to decrease the quantity traded (from Q_M to Q_M^R to Q_N). However, in the case of Form 2 this impact on relative bargaining power creates a conflicting tendency for an increase in quantity traded, which for the example of Z has been chosen to dominate the initial decreasing tendency (from Q_W to Q_W^R to Q_Z).

As a consequence of this argument, we conclude that in the case of Form 2 of the bilateral monopoly model “royalties can have an overall positive impact on production if the royalties induce a strong enough shift in the balance of bargaining power towards the buyer” (p5). But more generally, we conclude that “the analysis of Form 2 of the bilateral monopoly model does not support the view that royalties decrease production” (p5).

Subsequent research reported in Fraser and Rygnestad (1999) includes evidence to support the view that the iron ore trade between Australia and Japan can be characterised by Form 2 of the bilateral monopoly model. Consequently, we suggest that in this situation there is no efficiency agreement to favour an RRT over the existing royalty system.

SECTION 3: The Expected Level and Variability of Tax Revenue

In this section I explore the evidence to date regarding the performance of the PRRT since its introduction in 1987. To supplement this evidence I include comparison data on the performance of both the Resource Rent Royalty (RRR) jointly applied (25%/75%) by the Western Australian and Australian governments to Barrow Island petroleum since 1986 and the ad valorem royalty jointly applied (40%/60%) by these governments to petroleum from the NWS.

Table 1 contains data on production, total tax revenue and tax revenue per barrel for the three petroleum tax systems since 1987. In what follows, comparisons are made focusing on the derived measure of tax revenue per barrel as this eliminates in particular the distorting impact on total tax revenue of the rapid development of NWS production in the last decade. In this context, Table 2 contains summary measures of the mean, standard deviation and coefficient of variation for the three petroleum tax systems. Note that Table 2 contains two sets of summary measures for the PRRT. PRRT(10) refers to the values calculated using the ten data points for the PRRT in Table 1. However, it can be seen from this table that the first two data points (1988, 1989) for tax revenue are zero, reflecting the initial excess of the carry-forward of deductible costs over revenues for those two years, as well as to a large extent for the third and fourth years. Although this pattern of tax revenue from the PRRT is an appropriate feature of the system in its early years, and is an important contributor to the perceived riskiness of revenues from such a system, in my view the shortness of the data period means that this feature is arguably of exaggerated importance in estimating the mean and standard deviation of tax revenue from the PRRT. Consequently, I have included PRRT(25) in Table 2, which represents a recalculation of the estimates including each of the last five data points

(1993-97) three more times, with the intention of producing a set of summary measures which is less affected by the start-up features of the PRRT.⁸ It can be seen that the outcome of this recalculation is a set of estimates for the PRRT which is closer to those for the RRR. Given that the RRR was introduced for an existing mine, thereby excluding such features from its data series, it is my view that PRRT(25) is a superior description of the performance of the PRRT to PRRT(10).

Turning to the specific content of Table 2, it can be seen that the results for mean tax revenue are consistent with the claims of Garnaut and Clunies-Ross (1975) for the RRT relative to other tax systems. Similarly, the results for the standard deviation confirm that this “greater expected revenue (is) achieved at the expense of greater uncertainty of receipts”. In particular, mean tax revenue for PRRT(25) is almost double that for the ad valorem system (4.60 compared with 2.32), but the standard deviation of tax revenue is almost three times the size (2.29 compared with 0.79). Given this difference in proportions, the coefficient of variation for PRRT(25) is approximately 50% larger than that for the ad valorem system.

However, having confirmed the conjectures of Garnaut and Clunies-Ross (1975) for the RRT relative to an Ad valorem system, the question remains as to whether the risk-return trade-off reflected in the results in Table 2 warrants a risk averse government switching from an ad valorem to an RRT-based system. This question is examined in the next section.

SECTION 4: Evaluating the Risk-Return Trade-off for Switching Tax Systems

The standard approach in the literature for integrating the consideration of risk and return is the method of expected utility (Newbury and Stiglitz, 1981). Based on this method, risk-return trade-offs can be evaluated using a second-order Taylor series expansion of the utility function, combined with a particular functional form to represent utility (Fraser, 1998).

In the specific context of a government collecting tax revenue (TR), the expected utility of tax revenue ($E(U(TR))$) is represented by:

$$E(U(TR)) = U(E(TR)) + \frac{1}{2} U''(E(TR)) \cdot \text{Var}(TR) \quad (5)$$

and the utility function can take the form:

$$U(TR) = \frac{(TR)^{1-R}}{1-R} \quad (6)$$

where: R = coefficient of relative risk aversion

$$= -U''(TR) \cdot \frac{TR}{U'(TR)}$$

Based on this specification, Table 3 reports details of the evaluation of the risk-return tradeoffs contained in Table 2 for a range of values of the risk aversion coefficient (R). In relation to these values, note that Indian peasant farmers have been estimated to have values of R between 0.5 and 1.2 (Newbury and Stiglitz, 1981), while estimated values for Australian farmers are between 0.1 and 0.7 (Bardsley and Harris, 1987). On this basis, I would expect the appropriate value for the attitude to risk of an Australian or state government to be at the lower end of the range in Table 3.

In addition, the results in Table 3 have been presented as ratios of the expected utility of tax revenue per barrel from one tax system relative to another, with the three profit-based sets of summary measures compared in turn with those of the ad valorem system. In general these results show that, for all specified levels of risk aversion, a government's perception of the expected utility from a profit-based tax system would exceed that of the ad valorem system. Moreover, this superiority applies even to the most unfavourable of the sets of summary measures for a profit-based system (PRRT(10)). Based on previous comments, I think the most appropriate result to focus on in Table 3 is that for $R = 0.3$ and PRRT(25), which shows the expected utility per barrel from the PRRT exceeding that from the ad valorem royalty by almost 60%.⁹

As an extension of these results, recall that the WA government receives 40% of tax receipts from the ad valorem system applying to the NWS, whereas it receives only 25% of tax receipts from the RRR applying to Barrow Island. Although this difference raises the possibility that for the Western Australian government its expected utility of tax receipts per barrel from the NWS exceeds that from Barrow Island, row (1) of Table 4 confirms that this is not the case. Moreover, row (2) shows that the WA government's share of tax receipts per barrel from the NWS would have to increase to well-above 50% (compared with 25% from Barrow Island) before it would view the two tax-sharing arrangements as equally beneficial. Needless to say, the Australian government's view of the relative expected utility is even more strongly in favour of the Barrow Island arrangement (for $R = 0.3$, the $E(U(TR))$ ratio is 2.08).

Finally in this section, consider the extent to which average ad valorem tax receipts from the NWS would have to increase for the perceived benefits from this tax system to equal those from the PRRT. Specifically, Table 5 contains results based on the level of average tax revenue per

barrel from the NWS which, for the same coefficient of variation of these receipts, just equates the expected utility of tax revenue per barrel between the two systems. Note that these results are evaluated only for $R = 0.3$, and for 1997 production from the NWS.

These results suggest that, compared with the expected utility-neutral application of the ad valorem system to the NWS, the average annual tax receipts from the existing ad valorem system are more than \$100m lower, and are arguably between \$300m and \$400m lower.¹⁰ An inexcusable folly for the nation? I think so.

CONCLUSION

Apart from the comments I made in Section 2 regarding efficiency, this address has ostensibly been an exercise in validating the characteristics of the RRT asserted by Garnaut and Clunies-Ross (see Section 1). In particular, on the basis of evidence relating to the performance of the PRRT and the RRR, I have shown that an RRT can be expected to yield higher average tax revenues, albeit at the expense of greater variability of those revenues, than an ad valorem tax system (Section 3). Nevertheless, for reasonable levels of risk aversion, the risk-return trade-off associated with switching from ad valorem royalties to an RRT is well worthwhile (Section 4).

I would like to conclude this address by focusing on one concern with the RRT which was mentioned only briefly by Garnaut and Clunies-Ross (1975), but then commented on in greater detail by Garnaut and Clunies-Ross (1979). This concern relates to the theoretical connection between rate-of-return regulation and the RRT. Specifically, in the 1975 paper they note in passing that “the marginal rate (of tax) would, of course, need to be kept significantly below 100% to maintain company interest in the efficient management of the project” (p281). However, in the 1979 paper they make the explicit connection that “a 100 per cent rate would be equivalent to the absolute rate-of-return regulations whose distorting effects are described by Averch and Johnson (1962)” (p196). These distorting effects relate to an incentive for over-capitalisation, or “gold-plating”, in order to reduce the firm’s actual rate of return on capital relative to the critical rate at which tax (or a rebate in the case of rate-of-return regulation) becomes payable. Any manifestation of this incentive in actual investment behaviour will result in overall tax receipts being lower than they would be otherwise. Moreover, concern over this feature may be an explanation for the reluctance of

state governments in Australia to embrace the RRT. Evidence to support this conjecture is provided by the actions of the Northern Territory government, which in its broad range of profit-based resource taxes has paid particular attention to allowable capital costs in the form of its “Capital Recognition Deduction” (Northern Territory Treasury, 1992).

What is clear from the economic literature is that disaffection with the rate-of-return method of regulation, and in particular its in-built incentive for over-capitalisation, prompted the development of the RPI-X form of regulation, first applied to the privatised BT in 1984, and now widely applied in situations of privatised monopoly power and referred to as price-cap regulation (Fraser, 1991, 1996). The essential feature of price-cap regulation is its focus on price rather than profit (as in rate-of-return regulation). In particular, a price-cap regulated firm is constrained to increase its price (or weighted sum of prices) by no more than the inflation rate less an adjustment for productivity gains (“X”). However, subject to this constraint, there is no limit to the profits which such a firm can earn. Consequently, firms subject to price-cap regulation have no incentive to over-capitalisation, and in fact have every incentive to cost efficiencies because of the absence of a constraint on profits.

Given the development of the price-cap method in regulation policy, and given the connection between the RRT and the (denounced) method of rate-of-return regulation, is there some way of utilising this development in regulation policy to deal with the incentive to over-capitalisation in the context of the RRT?

I think there is, but the modification to the RRT needs to take account of the shift in focus from firms with monopoly power to firms without. In particular, I suggest an associated shift in focus from a price-cap to a cost-cap. The RRT, as it stands, is a tax on profits, where the

firm has both the opportunity and the incentive to cost inefficiencies. But, if in the establishment of the operational form of the RRT the government and the firm negotiated an agreement over the allowable cost (its “cost-cap”) per unit of production (subject to an inflation clause), then not only would the government eliminate an element of variability in its flow of tax revenues, but also the firm would know that profits generated by cost reductions relative to its “cost-cap” would be untaxed.¹¹

In E.M. Foster’s “Howards End” the character Margaret Schlegel urges us to “only connect” (p174). I look forward to the time when my RRT “connection” to recent developments in regulation policy will justify its literary pretensions.

APPENDIX: On the “Expense of Greater Uncertainty about Receipts” of the RRT

The aim of this appendix is to demonstrate that the “expense” of the RRT, in terms of its greater variability of tax revenues relative to other resource tax systems, may in certain circumstances be very small, or even negative. In particular, it is shown that if a firm’s price and cost of production exhibit a strong enough positive correlation, then the variability of tax revenues from a profits-based tax is less than that of an ad valorem tax with an equivalent level of expected tax revenue. Since firms with high export and import profiles in their revenues and costs (respectively) will feature such a positive correlation in the presence of exchange rate fluctuations, and since firms with such profiles are common in the resource sector, I would argue this demonstration is of considerable relevance to state governments contemplating a switch from an ad valorem system to an RRT.

In what follows, the firm’s profit (π) is specified to be a function of an uncertain price (p) and uncertain cost of output ($c(q)$):

$$\pi = pq - c(q). \quad (A1)$$

Its objective is to maximise the expected utility of profit ($E(U(\pi))$) by the choice of output, where $E(U(\pi))$ is represented by a second order Taylor Series approximation:

$$\underset{q}{\text{Max}} \quad U(E(\pi)) + \frac{1}{2} U''(E(\pi)) \cdot \text{Var}(\pi). \quad (A2)$$

The firm’s expected profit ($E(\pi)$) and variance of profit ($\text{Var}(\pi)$) will depend on the type of tax regime it faces. In the case of an ad valorem royalty (v) on the value of production:

$$E(\pi_v) = (1-v)(\bar{p}q) - E(c(q)) \quad (A3)$$

$$\text{Var}(\pi_v) = q^2((1-v)^2\text{Var}(p)) + \text{Var}(c(q)) - 2(1-v)q \text{cov}(p,c(q)) \quad (\text{A4})$$

where: \bar{p} = expected price per unit of output

$E(c(q))$ = expected cost of output

$\text{Var}(p)$ = variance of price

$\text{Var}(c(q))$ = variance of cost of output

$\text{cov}(p,c(q))$ = covariance of price and cost of output.

In this case, the government's expected tax revenue ($E(\text{TR}_v)$) and variance of tax revenue ($\text{Var}(\text{TR}_v)$) are given by:

$$E(\text{TR}_v) = v \bar{p} q \quad (\text{A5})$$

$$\text{Var}(\text{TR}_v) = v^2 q^2 \text{Var}(p). \quad (\text{A6})$$

For a profits-based tax (t), the corresponding equations are:

$$E(\pi_t) = (1-t)(\bar{p} q - E(c(q))) \quad (\text{A7})$$

$$\text{Var}(\pi_t) = (1-t)^2(q^2(\text{Var}(p)) + \text{Var}(c(q)) - 2q \text{cov}(p,c(q))) \quad (\text{A8})$$

$$E(\text{TR}_t) = t(\bar{p} q - E(c(q))) \quad (\text{A9})$$

$$\text{Var}(\text{TR}_t) = t^2(q^2(\text{Var}(p)) + \text{Var}(c(q)) - 2q \text{cov}(p,c(q))). \quad (\text{A10})$$

In each case the firm's optimal level of output is found by differentiating equation A2 with respect to q and equating to zero:

$$\begin{aligned} U'(E(\pi)) \frac{\partial E(\pi)}{\partial q} + \frac{1}{2} U'''(E(\pi)) \text{Var}(\pi) \cdot \frac{\partial E(\pi)}{\partial q} \\ + \frac{1}{2} U''(E(\pi)) \cdot \frac{\partial \text{Var}(\pi)}{\partial q} = 0 \end{aligned} \quad (\text{A11})$$

where the associated derivatives for each tax system are given by:

$$\frac{\partial E(\pi_v)}{\partial q} = (1-v) \bar{p} - \frac{\partial E(c(q))}{\partial q} \quad (A12)$$

$$\begin{aligned} \frac{\partial \text{Var}(\pi_v)}{\partial q} = & 2q((1-v)^2 \text{Var}(p)) + \frac{\partial \text{Var}(c(q))}{\partial q} \\ & - 2(1-v)\text{cov}(p, c(q)) - 2q(1-v) \frac{\partial \text{cov}(p, c(q))}{\partial q} \end{aligned} \quad (A13)$$

$$\frac{\partial E(\pi_t)}{\partial q} = (1-t)(\bar{p} - \frac{\partial E(c(q))}{\partial q}) \quad (A14)$$

$$\begin{aligned} \frac{\partial \text{Var}(\pi_t)}{\partial q} = & (1-t)^2(2q \text{Var}(p) + \frac{\partial \text{Var}(c(q))}{\partial q}) - 2\text{cov}(p, c(q)) \\ & - \frac{2q \partial \text{cov}(p, c(q))}{\partial q}. \end{aligned} \quad (A15)$$

In order to compare numerically the performance of each of these tax systems I assume the cost function can be represented by:

$$c(q) = cq^x \quad (A16)$$

where: x = known increasing marginal cost parameter ($x > 1$)

c = random parameter

\bar{c} = expected value of c

$\text{Var}(c)$ = variance of c

$E(c(q)) = \bar{c} q^x$

$\text{Var}(c(q)) = q^{2x} \text{Var}(c)$

$$\text{so that: } \frac{\partial E(c(q))}{\partial q} = x \bar{c} q^{x-1} \quad (A17)$$

$$\frac{\partial \text{Var}(c(q))}{\partial q} = 2xq^{2x-1} \text{Var}(c). \quad (A18)$$

Also, by specifying

$$\text{cov}(p, c(q)) = \rho \sigma_p \sigma_c q^x \quad (\text{A19})$$

$$= \rho \sigma_p \sigma_c q^x$$

where: σ_p = standard deviation of p

σ_c = standard deviation of c ,

it follows that:

$$\frac{\partial \text{cov}(p, c(q))}{\partial q} = x \rho \sigma_p \sigma_c q^{x-1}. \quad (\text{A20})$$

Finally, I specify the following parameter values:

$$\bar{p} = 100$$

$$\sigma_p = 100$$

$$x = 3.25$$

$$\bar{c} = 10$$

$$v = 0.1$$

and the constant relative risk aversion form for the firm's utility function:

$$U(\pi) = \frac{\pi^{1-R}}{1-R} \quad (\text{A21})$$

with $R = 0.5$.

Table A1 contains details of the results of a numerical analysis where the extent of the variability of costs (σ_c), and the strength of the positive correlation between price and costs (ρ) have been varied to illustrate possible outcomes for the government. In addition, the rate of tax

for the profit-based tax system (t) has been chosen to achieve expected tax revenue-neutrality between the two systems.

The results in this table (see columns (1), (2), (3) and (4)) show that if, for a given level of cost variability ($\sigma_c = 12.5$), the positive correlation between price and costs is strong enough ($\rho = 0.9$), then an expected tax revenue-neutral switch from an ad valorem to a profit-based tax system will both increase the production level and the expected utility of profit for the firm, and decrease the variability of the government's tax revenues. It follows that with a small increase in the rate of its profit tax, the government could create a situation where the switch from the ad valorem system would improve efficiency, increase the firm's expected utility, increase the government's expected tax revenue and decrease the variability of this revenue!

However, columns (5) and (6) of Table A1 show that this outcome is contingent not only on the strength of the positive correlation between price and costs, but also on the level of cost variability.

Nevertheless, it can be concluded from the results in Table A1 that the existence of a strong positive correlation between price and costs creates a situation where the difference between the variability of tax revenue under an ad valorem and a profit-based tax system may be very small, or even negative.

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FOOTNOTES

- ¹ Note that at this time Craig Emerson was a member of the Prime Minister's staff.
- ² Note that Craig Emerson's PhD was completed at ANU, where both Ross Garnaut and Peter Lloyd were academics at the time.
- ³ Apart from the profit-based taxes applied to mining in the Northern Territory, I am not aware of any other profit-based resource taxation in Australia (Northern Territory Treasury, 1992).
- ⁴ For full details of the impact of the two tax systems on optimal decisions see Fraser (1999b).
- ⁵ This issue is developed further in Fraser (1999a).
- ⁶ Although in the appendix to this address I show that there are situations where this "expense of greater uncertainty" is very small or even negative.
- ⁷ The other two are gold (approximately \$5b) and wool (approximately \$4b). Note that 75% of gold is mined in Western Australia, and was subject to a royalty as of July 1998.
- ⁸ Note that, based on the data for the RRR, this period for a profit-based tax underestimates both the expected level and variability of receipts/bbl. Also, recall that, because the ad valorem royalty is strictly proportional to total revenue, its receipts per barrel are not affected by the expansion of NWS production over this period.
- ⁹ Note that using the constant relative risk aversion form for the utility functions means that scale (number of barrels) is not a factor determining these results.
- ¹⁰ The component mix of petroleum from the NWS differs from those regions where the PRRT is applied, with a much higher weight for natural gas. If natural gas is more profitable to produce than other forms of petroleum, then the values in Table 5 are underestimated.
- ¹¹ Recall that in the appendix it is shown that a positive covariance between prices and costs, even if only based on similar inflationary (eg exchange rate) causes, is a stabiliser of profits and therefore of tax revenues for an RRT.

Table 1
Data for the Three Petroleum Tax Systems

	Production (Mbbl)			Revenue (\$m)			Revenue/bbl(\$)		
	PRRT ¹	RRR ¹	Ad Valorem ¹	PRRT ²	RRR ³	Ad Valorem ⁴	PRRT	RRR	Ad Valorem
1988	210.14	6.27	30.09	0	57.87	36.60	0	9.23	1.22
1989	192.42	5.77	31.69	0	23.90	35.16	0	4.14	1.11
1990	219.38	5.42	55.85	42	45.49	97.94	0.19	8.39	1.75
1991	213.49	5.26	68.98	293	36.88	203.14	1.37	7.02	2.94
1992	218.22	5.32	76.30	876	32.58	192.28	4.01	6.12	2.52
1993	212.18	5.21	83.36	1389	25.93	177.84	6.55	4.98	2.13
1994	200.95	5.40	95.03	1072	29.26	239.63	5.33	5.42	2.52
1995	221.39	5.28	108.94	865	19.58	261.57	3.91	3.71	2.40
1996	191.81	4.98	140.43	791	9.84	431.22	4.12	1.97	3.07
1997	175.44	6.73	158.16	1310	16.72	558.41	7.47	2.48	3.53

Sources: 1. Commonwealth Department of Primary Industries and Energy (1998) *Petroleum Production Statistics* Petroleum and Fisheries Division, Canberra.

2. Commonwealth Budget Papers (1997) *Revenue Statistics 1985/86-1996/97* Vol. I, Canberra.

3. WA Department of Minerals and Energy (various years) *Barrow Island Royalty Trust Account Annual Reports*, Perth.

4. WA State Budget Papers (various years) *Estimates of Revenue and Expenditure*, Perth.

Table 2
 Summary Measures for the Three Petroleum Tax Systems
 (\$/bbl)

	Mean	Standard Deviation	Coefficient of Variation
PRRT(10)	3.30	2.76	0.84
PRRT(25)	4.60	2.29	0.50
RRR	5.35	2.39	0.45
Ad Valorem	2.32	0.79	0.34

Source: Table 1

Table 3
 Evaluation of Risk-Return Tradeoffs for
 Profit-based and Ad Valorem Tax Systems

	R		
	0.3	0.6	0.9
E(U(TR)) Ratio			
(1) $\frac{\text{PRRT}(10)}{\text{AdValorem}}$	1.20	1.07	1.01
(2) $\frac{\text{PRRT}(25)}{\text{AdValorem}}$	1.59	1.29	1.06
(3) $\frac{\text{RRR}}{\text{AdValorem}}$	1.78	1.38	1.08

Table 4
 Evaluation of the Western Australian
 Government's Risk-Return Trade-off

	R	0.3	0.6	0.9
(1) E(U(TR)) Ratio:				
RRR(25%)/Ad Valorem (40%)		1.28	1.15	1.03
(2) Balancing Ad Valorem Share (%)		57.0	56.3	55.6

Table 5
 Required Increase in NWS Tax Receipts to Balance
 E(U(TR)) Per Barrel with the PRRT

Comparison Data Base		
	PRRT(10)	PRRT(25)
Average Tax Receipts		
\$ Per Barrel ^a	0.69	2.19
\$m Per Annum ^b	109	346
Notes		
a:	Based on R = 0.3	
b:	Based on 1997 NWS production = 158 Mbbl	

Figure 1

Impact of the RRT and Royalties on Profit

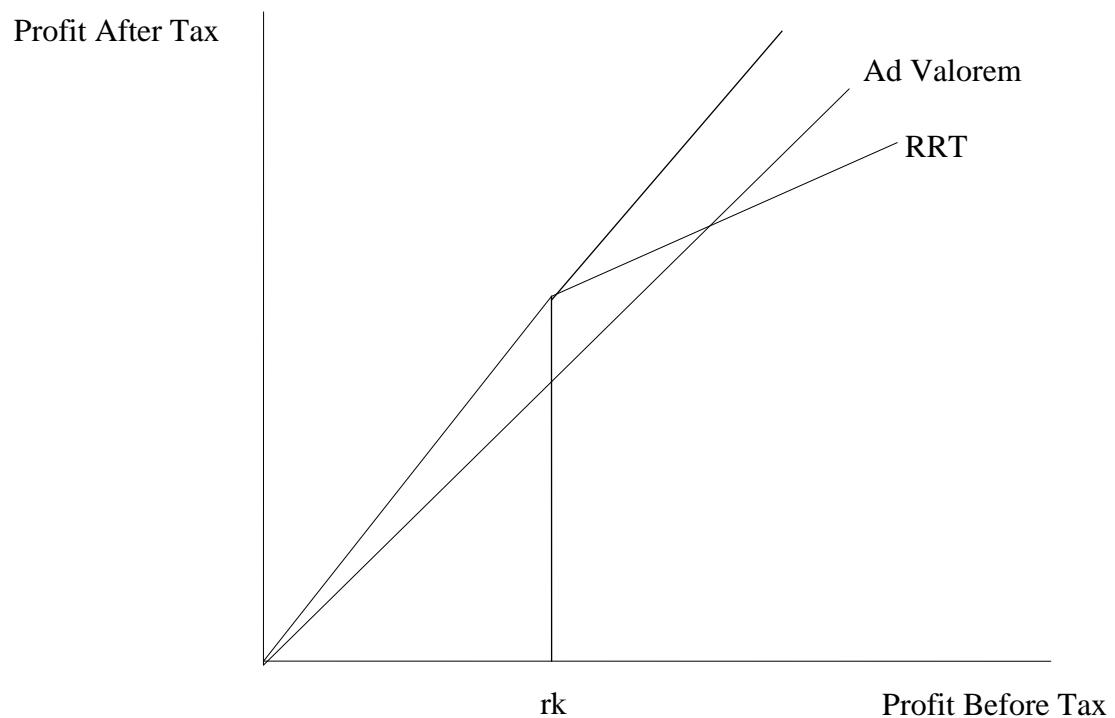


Figure 2

Bilateral monopoly with royalties: Form 1

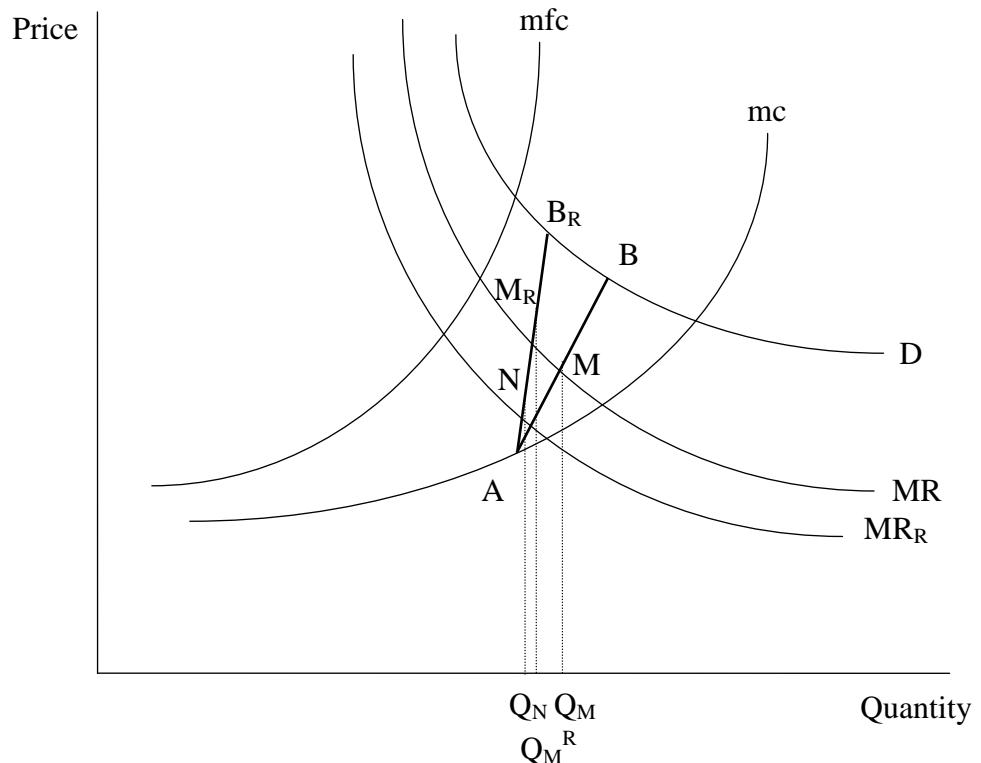


Figure 3

Bilateral monopoly with royalties: Form 2

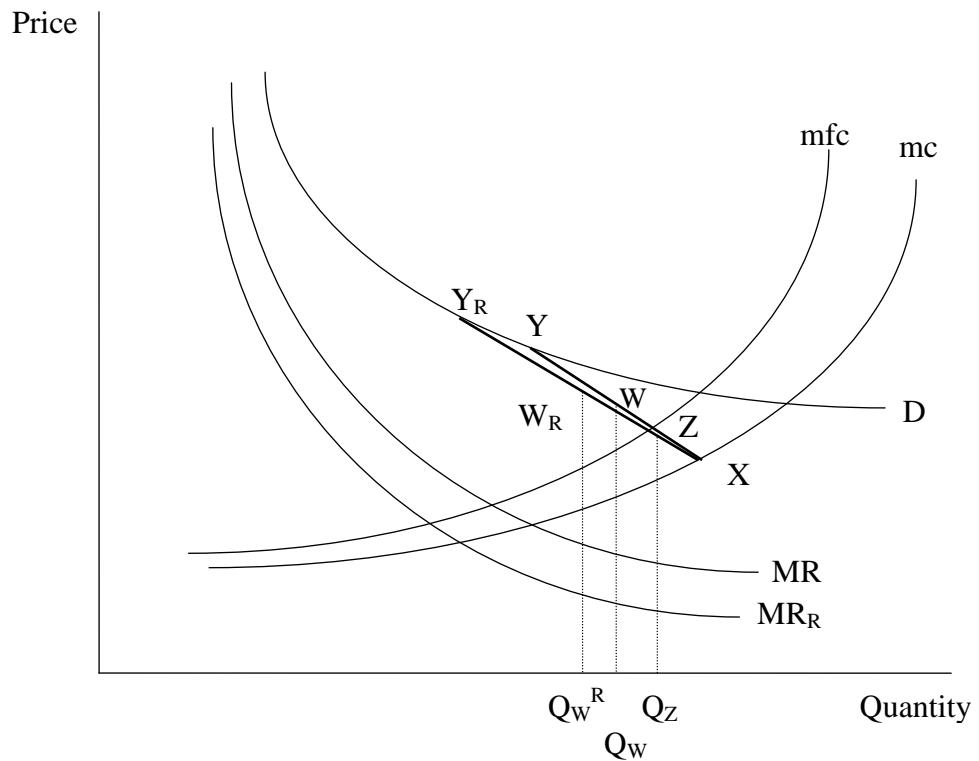


Table A1
Numerical Analysis of the Two Tax Systems

	$\rho = 0.7$		$\rho = 0.9$		$\rho = 0.9$	
	$\sigma_c = 12.5$		$\sigma_c = 12.5$		$\sigma_c = 5$	
	(1) Ad Valorem	(2) Profit-based ^a	(3) Ad Valorem	(4) Profit-based ^b	(5) Ad Valorem	(6) Profit-based ^c
q	1.44	1.51	1.57	1.64	1.38	1.44
E(π)	96.80	98.31	97.88	98.29	95.50	97.45
Var(π)	11056.44	11405.85	9123.99	9204.15	12376.25	12889.86
E(U(π))	16.78	16.91	17.43	17.47	16.23	16.39
E(TR)	14.41	14.41	15.68	15.68	13.75	13.75
Var(TR)	207.60	244.45	245.71	233.54	189.05	256.03

Notes: a: $t = 0.128$
 b: $t = 0.137$
 c: $t = 0.123$