The valuation of oil and gas reserves

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Executive summary

This paper explores a number of issues involved in making a valuation of the UK's oil and gas reserves. It can be seen as part of a wider move to develop environmental accounts which extend the main national accounts so that they are more relevant to environmental concerns such as sustainable development.

The paper first investigates the physical quantities of oil and gas that are estimated to exist on the UK Continental Shelf (Section 2). As might be expected, there is a wide range of uncertainty about the quantities that might be producible in the future. Taking account of the estimated probability of being able to extract these reserves, we estimate that at the end of 1998 the expected amount of oil was 1,535 million tonnes, of which only 685 million tonnes has been proven. The corresponding figures for gas reserves are 1,780 billion cubic metres expected to be extracted, of which only 755 bcm has been proven. It is clear that the estimates of the present value of oil and gas reserves will be very sensitive to these estimates.

We then calculate the present value of these reserves assuming that investors in oil and gas companies receive an 8% real rate of return on the capital invested. The estimates of present value are sensitive to the rate assumed, particularly for oil reserves, where the value in 1998 reduces by over 30% for each additional percentage increase in the rate of return on capital that is assumed (Table 4).

The estimates are also sensitive to assumptions about the future prices of the extracted resource, particularly for oil where prices can fluctuate dramatically. If we assume that future unit rents are equal to a moving average of the last two years' figures (instead of simply the latest figure), the estimated present value at the end of 1998 more than doubles for the oil sector. It decreases for the gas sector by only 3% (Table 6).

The estimates of present value are less sensitive to a number of other assumptions that need to be made. For example, if we assume that the amounts of oil and gas that are extracted reduce steadily over time (rather than remain constant), the estimated value of the reserves reduces by between 3% and 4% (Table 5).

Similarly, the estimated present value obtained under the assumption of a 3% social discount rate rather than a 4% discount rate increases by only 5% and 8% for the oil and gas sectors respectively (Table 7).

There is also a great deal of uncertainty about the size and timing of any decommissioning costs that might be incurred by the oil and gas industry. If we assume that decommissioning costs will total £16 billion in 1998 prices, we estimate that the present values of oil and gas reserves at the end of 1998 will be 5% lower than if there were no decommissioning costs (Table 8).

The ONS has calculated a summary balance sheet for 1998 using the following preferred package of assumptions:

- a rate of return on capital of 8%
- decreasing levels of extraction over time
- a constant future unit rent equal to the average of the previous two years
- a social discount rate of 4%
- decommissioning costs of £16 billion payable at the end of the life of the reserves

Under these assumptions, the values of oil and gas reserves at the end of 1998 were estimated to be £20 billion and £30 billion respectively (Table 9). The value of the amounts extracted during 1998 is estimated to be £2.25 billion and £2.5 billion respectively (Table 12).

There are a number of areas where further work would be desirable (Section 7). These include

- the development of plausible sets of maximum and minimum assumptions, in order to determine a reasonable range for the valuations;

- the development of a full balance sheet analysis for the preferred package of assumptions, taking into account any new international work on the issue of estimating depletion;

- refining the assumptions about the price basis of the estimates and the relationship between total calendar year and end year values;

- linking receipts of specific taxes and royalties made in the year with the revenue from sales for any particular year. At the moment the relationship between receipts of taxes and sales revenues is not clear and it is not possible to make a meaningful allocation of the value of the oil and gas reserves between the Government and the extraction industries.

1 Introduction

1.1 The aim of this note is to explore options for the calculation of a monetary value for the UK oil and gas reserves. It is part of the wider development of integrated environmental and economic accounts and builds on earlier work on the valuation of oil and gas reserves carried out by the ONS and published in April 1996[1].

1.2 Environmental accounts are a relatively new phenomenon, reflecting increasing concern with sustainable development and the effect of the economy upon the environment. The UK environmental accounts are being developed as a satellite to the main national accounts, in the sense that they either extend the definitions used in the main accounts or they re-present information which is already covered by the main accounts. There are no formal international standards as yet, but the accounts are consistent with the standards emerging from a draft UN handbook on a System of integrated Environmental and Economic Accounts (SEEA)[2] and from collaboration with other member states of the European Union under the auspices of the Statistical Office of the European Communities (Eurostat).

1.3 Broadly speaking, environmental accounts aim to present a picture of the stocks and flows of environmental resources in a way that can be linked in physical (and, where appropriate, monetary) terms with the description of the economy available from the main national accounts developed under the System of National Accounts (SNA 1993)[3]. In the case of natural resources such as oil and gas reserves, this means starting with the 1993 SNA definition used in building asset accounts, but extending it to cover other categories of reserves. It also implies a different treatment of depletion in the production accounts.

Differences between the environmental satellite accounts and the 1993 SNA

1.4 In the 1993 SNA, assets are defined as entities that are owned by some unit or units and from which economic benefits are derived by the owner(s) by holding them or using them over a period of time. In the case of oil and gas, only the reserves which have been physically proven are recognised in the accounts. Since proving reserves is expensive, extraction companies only tend to prove the reserves which they need to ensure continuity of production. As a result, proven oil reserve levels in the UK have not decreased at all in the last seventeen years, even though production in cumulative terms over that period has exceeded the estimated amounts of proven reserves in 1981 by a factor of 2.8.

1.5 It seems clear that a more realistic assessment of the expected levels of reserves would provide a better basis for the assessment of sustainable wealth, and the degree to which produced capital can continue to be based upon the consumption of natural assets. In order to do this the definition of the asset boundary in the 1993 SNA has to be extended in the satellite account to cover assets which may not currently be providing economic benefits (or which are uneconomic at the moment) but which have the potential to do so in the future, and assets whose existence has not been proven or over which ownership rights cannot yet be established. These are known as the recognition of option and bequest benefits. It is important, however, to recognise that there is a risk that such reserves may never be exploited and thus asset values might be overstated.

1.6 The satellite accounts also take a different approach to the treatment of depletion. The 1993 SNA records depletion as "other changes in volume", and not as costs which are to be accounted for in the production accounts. By contrast, the environmental accounts consider depletion as consumption of the asset and hence as a deduction from the value-added of the relevant industry.

1.7 There is some debate over whether the allowance for depletion in the environmental accounts should be used to adjust the figure for Gross Domestic Product (GDP) or the Net Domestic Product (NDP). The difference between the two in the 1993 SNA is the allowance for the consumption of fixed capital (depreciation). The NDP is theoretically a more relevant figure in assessing the performance of the economy even though, in practice, it is the GDP figure which is more widely used, because of the difficulties in obtaining reliable estimates of depreciation,.

1.8 The debate is concerned with whether a subsoil asset is like a capital asset, which is progressively consumed (depreciated) over time, or an inventory which might be run down over a period of time. Since subsoil assets cannot be used repeatedly in production, the general consensus is that they are more similar to inventories: they exist as more or less homogeneous stocks from which matter is gradually withdrawn and they are subject to quantitative depletion through human use. However, the analogy should not be pressed too far: stocks of sub soil assets cannot be increased by human activity (if one accepts that the total reserves are finite in the first place); they may represent several years', if not centuries', worth of demand; and the amounts involved are difficult to measure with any certainty. It is in this last sense that estimates of depletion are most like estimates of depreciation, and there is a strong argument for treating them in the same way by including a separate allowance for depletion alongside the allowance for depreciation ie by calculating an adjusted NDP but not an adjusted GDP.

Units of measurement

1.9 Environmental accounts present information in both physical and monetary terms. The advantage of monetary accounts is that they provide for aggregation of different assets on a consistent basis, since it is often difficult, if not impossible, to aggregate different assets meaningfully in physical terms eg tonnes of oil cannot be directly equated to cubic metres of gas. However, it is quite possible for the costs of depletion to be shown as decreasing despite the fact that more of the resource has been extracted (for example, when the price of the resource has gone down). It is therefore important to ensure that physical depletion figures are available alongside estimates of monetary changes in order to understand fully the extent of depletion of natural assets such as oil and gas.

Structure of the paper

1.10 The note is organised as follows. In the next section, we consider the issues involved in calculating the physical accounts of reserves and their life expectancy. In section 3 we discuss valuation issues, including how to calculate the economic rent attributable to the reserves. Section 4 sets out the calculation of the value of the reserves, using the method of present value. Using a set of simplified assumptions, the value of the reserves is calculated for all the years between 1990 and 1998. A number of different assumptions about the rate of return on capital, the rate of extraction, the social discount rate, the unit rent attributable to the natural asset and the effect of decommissioning costs are examined, and the present value of the reserves at the end of 1998 on the basis of a "preferred package" of assumptions is then calculated. Section 5 presents a view of the balance sheet of oil and gas reserves for the year 1998 and section 6 discusses the ownership issue and provides estimates of the proportion of the rent that can be attributed to Government and the extraction companies. The final section identifies the scope for further work.

2 Oil and gas reserves in physical terms

2.1 In this section we set out how to calculate the stock of UK Continental Shelf (UKCS) oil and gas reserves in physical terms.

2.2 Oil and gas reserves are not homogeneous resources. Reserves are classified by the Department of Industry (DTI) under two categories: discovered and undiscovered. Discovered reserves can be divided into three different categories according to their degree of practical producibility under the existing economic and technological conditions: proven, probable and possible. More precisely, "proven reserves are known reserves which, on the available evidence, are virtually certain to be technically and economically producible, ie having a better than 90% chance of being produced. Probable reserves are known reserves which are not yet proven but which are estimated to have a better than 50% chance of being technically and economically producible. Possible reserves are those reserves which, at present, cannot be regarded as 'probable', but are estimated to have a significant , but less than 50%, chance of being technically and economically producible" (The Energy Report, 1998[3]).

2.3 Undiscovered reserves are reserves which are yet to be discovered, but which may exist in areas of the UKCS. Monte Carlo simulation techniques are used to give estimates of the range of undiscovered reserves whose lower and upper bound should not, however, be taken as a maximim or minimum. Nevertheless, in the absence of any other information about the probability of producing these reserves (under current conditions) it seems prudent to take the lower bound estimate as the expected value.

2.4 It follows that, in the absence of any other information about the probability of producing oil and gas from the UKCS, the best estimate of the amount of discovered reserves that we can expect to extract has to be based upon the amount which we estimate to be producible with 50% probability ie the sum of proven and probable reserves. To this estimate we need to add a (prudent) allowance for undiscovered reserves.

Expected Level of Reserves = proven + probable + lower bound of undiscovered reserves

Table 1

Calculation of the expected level of oil and gas reserves

Reserves at end year 1998	**Oil (million tonnes)**	**Gas (billion cubic metres)**
Discovered – Proven	685	755
- Probable	575	585
- Possible	540	455
Undiscovered reserves		
- lower bound	275	440
- upper bound	2,550	1,595
EXPECTED RESERVES	**1,535**	**1,780**

Source: The Energy Report, 1999

Estimates of reserves for the years 1990 to 1998 are given in Annex A. Figures for the expected level of reserves for the years 1990 to 1998 are given in Table 10 below.

Life expectancy of reserves

2.5 The life expectancy tells us how many years the reserve is expected to last. This is a crucial factor in the calculation of the present value (see section 4).

2.6 The life expectancy can be obtained by dividing the total volume of reserves at the end of the year by the quantity extracted during that year. This assumes that production in the most recent year will continue into the future at the same level.

The following figures are for end-year 1998; Table 10 shows a physical balance sheet with life expectancy figures for 1990 to 1998.

Life expectancy = stock at the end of the year / current extraction

End year 1998

Oil
Life Expectancy = 1535 / 133 = 12 years

Gas
Life Expectancy = 1780 / 96 = 19 years

2.7 It is probably not realistic to assume constant extraction levels over time, since as each oil and gas field comes out of production the annual rate of extraction will drop. In fact, latest estimates[5] suggest that the annual quantity extracted will be broadly constant for four more years before decreasing by a roughly constant amount every year, assumed to be equal to 8 million tonnes for the oil sector and to 3 billion cubic metres for the gas sector, so that the fields will be almost completely exhausted by 2018 and 2032 for oil and gas respectively:

End year 1998

Oil
Life Expectancy (decreasing extraction rate) = 20 years

Gas
Life Expectancy (decreasing extraction rate) = 34 years

2.8 The different assumption about future extraction rates produces a different life expectancy and different estimates of the value of reserves if the future income stream they generate is discounted. For this reason, in section 4, we consider two possible scenarios: constant and decreasing annual extraction rates.

3 The monetary valuation of reserves

3.1 Having made estimates of the physical quantities of reserves, we can now proceed to attribute values to them. The valuation of such natural resource asset stocks for the environmental accounts, as for the SNA, should ideally be based on observed market values for transactions in the assets. Where such values are not available, indirect estimation of market values rests first on the estimation of a return to the resource, often referred to as economic or resource rent.

3.2 The resource rent for a given asset is defined empirically as the difference between total revenue generated from the extraction of the resource and all the costs incurred during the extraction process, including the cost of produced capital, but excluding specific taxes on extraction, royalties and costs that are not directly related to the extraction process.

Resource rent = total revenue - costs (excluding specific taxes and royalties but including an allowance for the cost of produced capital)

3.3 The resource rent could be estimated in a different way. As the Government holds rights over the natural assets extracted by the oil and gas companies, in theory the resource rent could be entirely appropriated by Government through the taxes and royalties which the Government levies on the extraction companies. It might be argued that the tax regime embodies an assessment of acceptable profitability and that the current rent income therefore equates to the sum of the current specific taxes and royalties imposed on the extractors. In practice there are a number of limitations to this methodology which are discussed more fully in section 6.

3.4 Adoption of the method described in paragraph 3.2 also has its limitations, but it appears to be a more objective method of calculating rent, avoiding the judgement as to whether the Government is attempting to collect, or successful in collecting, the entire resource rent in every year. The comparison of the results with the revenue received by the Government in taxes and royalties is covered in section 6 below.

Calculation of resource rent

3.5 The calculation of resource rent, using the definition in paragraph 3.2, requires a number of assumptions to be made about the level of capital formation in the oil and gas industry and the most appropriate allowance for the costs of produced capital.

Capital stock and capital consumption

3.6 The amount of capital investment in the oil and gas industry changes over time, due to new gross capital formation net of capital consumption (depreciation). Capital depreciation is calculated by reference to the life expectancy of plant and machinery plus some allowance for the sums invested in development and exploration (which in the 1993 SNA are treated as investment rather than operating expenditure). For the oil and gas industry, the available information on exploration costs does not explicitly differentiate between oil and gas, and hence the capital stock and capital consumption estimates are generally available only for the sector as a whole. For the purposes of this paper we have assumed that both capital stock and capital consumption are split between oil and gas *pro rata* to the share of development costs. In order to smooth out variations between years a ten-year weighted moving average has been used. The figures used are given in Annex B.

Return on capital

3.7 Estimating the return on capital is not theoretically straightforward, as there are at least two ways in which the concept can be interpreted. First, it could be interpreted as the opportunity cost of the investment in the capital assets, which could be estimated by reference to the average real rate of return on investment elsewhere in the economy. Alternatively, the return to capital could be viewed as covering the cost of financing the acquisition of the capital stock. The draft SEEA manual[2] adopts the second interpretation and recommends the use of a nominal interest rate based on long term industrial bond rates (a nominal rate on the assumption that capital goods used in resource extraction are fully depreciated and not sold in order to realise any gain in the assets' value). The Eurostat Task Force[6] has adopted the first interpretation and has recommended a rate of around 8% in real terms. This note follows the recommendation of the Eurostat Task Force.

3.8 There is in any case uncertainty regarding the estimation of the return on capital, particularly when the resource rent is small. In the case of coal and gold, for example, resource rents sometimes become negative after the deduction of an allowance for the return on capital. Fish stocks in the North Sea have also been shown to have negative resource rents for a number of years (see NOREEA[7]). Negative resource rents suggest that the assumptions made regarding the return on capital may be inappropriate, perhaps because they fail to recognise that lower rates of return may apply in the subsoil resource extraction industries. It may therefore be appropriate to assume a much lower return on capital - such an assumption would yield an upper bound to the estimated level of resource rent. This note has not attempted to calculate such an upper bound to the value of the UK's oil and gas reserves although it would be relatively straightforward to do so.

3.9 As a working assumption the rate of return on capital is assumed to be equal to 8%, although we test the effect of alternative assumptions. The value of 8% is derived from the data available on the profitability of manufacturing industries (across the EU) and therefore reflects the average return investors should expect to obtain in the oil and gas industry. It seems reasonable to look for a common rate all over Europe and we agree with the Eurostat Task Force[6] that 8% "should be taken as the default value in absence of more detailed information".

3.10 It has been argued that the rate of return on capital investment within the oil and gas industry will be higher than in the rest of the manufacturing sector because of the extreme volatility of product prices and the uncertainity over successful exploration. Against this it can be seen that the fiscal regime, which guarantees some protection from price changes, acts to dampen the inherent uncertainties over future revenues in the sector. On balance there do not seem to be any compelling grounds for assuming significantly higher rates of return, and some evidence (ie negative resource rents) that lower rates might have applied in the past.

3.11 The total rents for the oil and gas sectors for 1998 have been calculated as shown in Table 2; full details for other years are given in Annexes B and C.

Table 2

Calculation of total resource rent for oil and gas, 1998

£ million, current prices

	Oil	Gas
Total revenues	10,258	6,781
Less Operating Costs	-3,146	-1,153
Less Capital consumption/ Depreciation Allowance	-3,658	-1,742
Less Return on Net Fixed Capital	-2,480 (2,790)	-1,180(1,328)
Total Resource Rent	**974 (664)**	**2,706 (2,348)**

Note: numbers in parenthesis refer to the alternative assumption of a rate of return on capital of 9%.

Unit resource rent

3.12 We obtain the unit resource rent for a year by dividing the total resource rent by the quantity sold in that year. For convenience, the amount sold is taken to be equal to the amount produced.

1998, current prices

	Oil £ per tonne	**Gas £ per thousand m^3**
Unit resource rent	974 / 133 = £7	2,706 / 96 = £28

3.13 The approach taken is to assume that the real unit resource rent will remain constant over time. An argument against this assumption is that unit resource rents have fluctuated markedly in the recent past. For this reason, a more realistic assumption might be to calculate the unit resource rent based on a moving average of values from the last few years (see paragraphs 4.8 and 4.9 below).

3.14 It might also be argued that future production costs will increase as the more readily accessible reserves are depleted, implying (assuming constant unit sale prices) that the unit resource rent will decrease over time. This assumption would tend to lead to a lower present value to the reserves, but the question as to whether the current allowance for depletion should also be lower has not yet been explored.

4 The present value of reserves

4.1 The monetary value of oil and gas reserves might in theory be calculated according to the value that the market attributes to them, as in the case of a capital asset. However, the sporadic nature of the transactions associated with natural resources constitutes a constraint to this method. In the absence of this market information, the value can be taken as equal to the expected flow of future incomes - appropriately discounted - that the reserves provide over time. This method is generally agreed internationally as the most appropriate one for valuing oil and gas resources[α].

4.2 The net present value of oil and gas reserves at the beginning of year t is given by the following formula, assuming a constant real unit resource rent and a constant extraction rate over time (ie constant real total resource rent):

$$PV_t = q_t r_t \left(1 - \frac{1}{(1+i)^n} \right)$$

Where:

r_t is the expected future unit rent, assumed constant over the period and assumed to be equal to the unit rent in the previous year. We also assume for convenience that the total rent is received at the end of each year;

q_t is the expected future quantity of extraction in year t, assumed to be equal to the quantity extracted in the previous year;

(1+i) is the social discount factor, and "i" is, therefore, the social discount rate. This rate can be approximated by the interest rate on low risk bonds[β]. The

[α] An alternative (the net price method) is based upon the so-called Hotelling rule, which is that the resource price should rise as scarcity increases, offsetting the effect of discounting the flow of future incomes. There is little empirical evidence in support of this model, and it seems unlikely to apply in the case of the UK's oil and gas reserves.

[β] The choice of discount rate is a very debatable issue as it involves balancing considerations of intergenerational equity (the discount rate should be equal to zero in this case), social time preference, the social opportunity cost of capital and (in the case of oil and gas) the degree to which fossil fuels will be substitutable in the future or will prove to have other economic uses.

precise value is fairly arbitrary but a figure of 4% has been considered acceptable by the Eurostat Task Force[6]. The discount rate takes into account time preference - the preference of an asset's owner for income today rather than in the future. It could also be used to take into account the risks associated with the future returns expected from the assets, such as the possibility of price or cost changes and uncertainty about availability of reserves and the future extraction path;

n is the expected life of the reserves, given the assumption of a constant annual rate of extraction over time.

The impact of decommissioning costs is considered separately, in paragraphs 4.12 to 4.16 below.

4.3 In Table 3 we provide estimates of the estimated present value of oil and gas reserves from end year 1990 to end year 1998, on the basic assumption of an 8% rate of return on capital and constant total future resource rents. The present value of oil reserves decreased for the first three years and then recovered to peak at £53 billion at the end of 1996 before falling dramatically to £9 billion (in current prices) by the end of 1998. Gas reserves are estimated to have had no positive value (shown in the table as negative, although this is not strictly possible) in the first three years before similarly recovering to £34 billion at the end of 1996. However values have been maintained at around this level at the for 1997 and 1998.

Table 3

Present value of oil and gas reserves in current prices, start of every year, assuming constant current unit rents, constant extraction rates, an 8% return on capital and a social discount rate of 4%

£ million, current prices

Present value at end of year	Oil	Gas
1990	24,135	-9,923
1991	9,712	-1,433
1992	8,057	-412
1993	13,734	8,688
1994	26,951	18,050
1995	36,246	21,029
1996	52,725	34,267
1997	34,628	31,370
1998	8,884	35,052

* Strictly speaking, natural resources cannot have negative values; they have been shown as such in order to allow a full understanding of what the data reveals.

The effect of different assumptions about the rate of return on capital

4.4 The present value of reserves at the end of 1998 under different assumptions about the rate of return on capital is given in Table 4.

Table 4

Present value of oil and gas reserves in current prices, start year 1999, assuming constant extraction rates and constant current unit rents and a social discount rate of 4%, with alternative assumptions about the rate of return on capital

£ million, current prices

Present value at end of 1998	Oil	Gas
Assuming 8% return on capital	8,884	35,052
Assuming 9% return on capital	6,056	33,140
Assuming 10% return on capital	3,228	31,229

4.5 Table 4 shows that estimates of the present value of oil reserves are fairly sensitive to the assumed rate of return on capital, depending upon the size of the resource rent. A larger return on capital cuts into the rent attributable to the natural asset and reduces the present value of the resource. For the gas sector the decrease in the present value amounts to about £1.9 billion (5%) for each percentage point increase in the rate of return on capital. For oil the reduction in the value in 1998 is more significant, particularly in relative terms - being equivalent to about £2.8 billion or at least 30% for each additional percentage rate of return. Because the rent for oil was historically low in 1998 the effect in relative terms is rather more significant than it would be for other years in the recent past. It follows that the estimated value would be considerably less sensitive to different assumptions if we assumed that future unit resource rents were equal to the average of the figures for the previous two years (see paragraph 4.8 below).

The effect of different assumptions about the rate of extraction

4.6 As explained in paragraph 2.7 above, the assumption that future production continues at the same level as the most recent year is probably not realistic. If we assume that the quantity extracted decreases by a constant physical amount each year (after say being constant for the next four years), the formula is somewhat more complex but the principle is the same: it is the sum of each year's rent, appropriately discounted. The results for 1998 (end of year) are:

Table 5

Present value of oil and gas reserves in current prices at the end of 1998, assuming constant current unit rents, an 8% return on capital and a social discount rate of 4%, assuming different extraction rates

£ million, current prices

Present value end of 1998	Oil	Gas
Assuming constant extraction rates	8,884	35,052
Assuming decreasing extraction rates	8,624	33,091

4.7 It can be seen that the value of the reserves is reduced slightly if a more realistic assumption about the rate of extraction is made. Assuming a uniform reduction in the extraction rate (after four years), the present value drops by 3% and 5% for oil and gas respectively. The effect is proportionately greater for gas because gas reserves have a longer life expectancy.

The effect of different assumptions about future unit rent levels

4.8 The effect on the present value of assuming that future unit rents are equal to the average of the latest two years is illustrated in Table 6.

Table 6

Present value of oil and gas reserves in current prices at the end of 1998, assuming constant extraction rates, an 8% return on capital and a social discount rate of 4%

£ million, current prices

Present value end of 1998	Oil	Gas
Assuming future unit rent equals latest unit rent	8,884	35,052
Assuming future unit rent is average of last two years	20,584	31,302

4.9 As expected, the estimated value of oil reserves at the end of 1998 is significantly higher if future unit rents are based on an average of recent years. The opposite is true for gas, where the unit rent in 1997 is estimated to be lower than the figure for 1998.

The effect of assumptions about the social discount rate

4.10 We can also test the effect on the estimate of the present value of different assumptions about the social discount rate:

Table 7

Present value of oil and gas reserves in current prices at the end of 1998, assuming constant current unit rents, constant extraction rates and an 8% return on capital, with alternative assumptions about the social discount rate

£ million, current prices

Present value at the end of 1998	Oil	Gas
Assuming social discount rate of 4%	8,884	35,052
Assuming social discount rate of 3%	9,405	38,172

4.11 Clearly, the higher the weight given to future generations (by reducing the social discount rate), the higher the present value of the current reserves. Because the life expectancy of gas reserves is greater than that for oil, the relative effect of assuming a lower social discount rate on the estimated value of the reserves is greater for gas (9%) than for oil (6%).

Decommissioning costs

4.12 Decommissioning costs such as the deinstallation costs of oil and gas rigs occur at the end of the life of a capital asset. They represent a significant overhead in the oil and gas industry and they affect the calculations of the future income stream from the subsoil asset. Since the costs are to a certain extent already known in advance it should be possible to take them into account in the present value calculation.

4.13 The costs can be treated in one of two distinct ways. First, they can be viewed as costs (net of any residual scrap value) which should be taken into account in calculating the resource rent. Under this treatment, the costs are spread over the "life of the liability" in much the same way as the costs of generating capital investment are spread over time, by allocating a share of the total decommissioning costs to each year in the life of the capital asset. (The costs cannot be treated as fixed capital as they cannot provide any additional service in the future.) For the purposes of this paper the costs have been allocated between oil and gas for each year *pro rata* to the historic and expected resource rents[χ].

4.14 The second option is to treat the costs as one-off payments which reduce the present value of the reserves without reducing the resource rent. Under this option the total decommissioning costs, suitably discounted, are subtracted from the Net Present Value which would otherwise have been obtained. The difficulty with this approach is that the costs are never accounted for in the calculation of resource rent or in the estimate of depletion. The approach is not favoured by the ONS, especially as it appears likely that the UK Government will make a significant contribution towards the costs of decommissioning oil and gas rigs [source?] (a contribution which could be viewed as being funded by the specific taxes and royalties received by the Government when the rig was in operation).

4.15 Although there is uncertainty over how the decommissioning costs are to be funded, this should not affect the calculation of the present value. It will, however, affect the shares of the value that are allocated to the Government and to the extraction companies (see section 6 below). The exact amounts involved, and the timing of such payments, are of course also uncertain. In this paper we have assumed

i. that the total costs will be £16 billion in 1998 prices (source[9]), split between oil and gas *pro rata* to cumulative development costs;
ii. that the costs will all be incurred at the end of the life expectancy of the reserves (which is dependent upon the assumption about future extraction rates);
iii. that the costs will be borne 70% by the Government and 30% by the industry.

4.16 Table 8 provides estimates of the present value of oil and gas reserves taking into account decommissioning costs based upon these assumptions:

[χ] This approach is similar to that proposed by Harrison[8], the difference being that no adjustment to capital stock or capital

Table 8

Present value of oil and gas reserves in current prices at end of 1998, assuming constant current unit rents, constant extraction rates, an 8% return on capital and a social discount rate of 4%, taking into account £16 billion decommissioning costs

£ million, current prices

Present value at end of 1998	Oil	Gas
Assuming no decommissioning costs	8,884	35,052
Assuming £16 billion decommissioning costs	8,467	33,410

Summary

4.17 Putting the above options together into one package, the ONS preference is to assume

- a rate of return on capital of 8%
- decreasing levels of extraction over time
- a constant future unit rent equal to the average of the previous two years
- a social discount rate of 4%
- decommissioning costs of £16 billion costed over the life of the reserves.

4.18 When these assumptions are combined, the estimated values of the UKCS oil and gas reserves at the end of 1998 are as follows:

Table 9

Present value of oil and gas reserves in current prices at end of 1998, assuming constant average unit rents, decreasing extraction rates, an 8% return on capital, a social discount rate of 4% and decommissioning costs of £16 billion

£ million, current prices

	Oil	Gas
Present value at end of 1998	19,927	30,411

consumption is involved.

5 The balance sheet for oil and gas assets

5.1 There are a large number of ways of accounting for the year-on-year changes in the value of oil and gas reserves. The analysis adopted in the first part of this section is based on the conclusions of the Eurostat Task Force[6], which however has only been fully worked through for the basic calculation where constant extraction rates, constant unit rents and no decommissioning costs have been assumed. On this basis, it is possible to decompose the change in the present value between the beginning and the end of year t into the five factors listed below. Let us call PV_t the present value at the beginning of year t and PV_{t+1} the present value at the end of the same year. The change in the present value will obviously reflect the fact that the life expectancy has decreased by one year and that reserves have reduced by the amount extracted during the year. However, other elements have also changed, such as the assumed unit rent and the assumed rate of extraction. The full calculation of each of the five elements is given below:

- *extraction* - the reduction in value resulting from the physical extraction from the reserves during the year given by the product of extraction and unit resource rent:

Extraction = $-R_t$

  where R_t refers to the total resource rent received in year t;

- *the time passing component*. This is a positive component reflecting the fact that we are discounting less as we approach the end of the life expectancy of the asset. This is calculated as the social discount rate times the present value at the beginning of the year, under the conditions of year t:

Time passing = i * $PV^{n',Rt}$

  where n' is the life expectancy consistent with the extraction rate in year t (and not year t-1), and $PV^{n',Rt}$ is the present value calculated at the beginning of year t;

- *Other volume changes*, such as new discoveries and revised estimates of the size or producibility of existing discoveries. This is due to the fact that new discoveries and other changes modify the life expectancy and therefore the present value:

Other volume changes = R_t * ($PV^{n'-1,Rt}$ - $PV^{n'',Rt}$)

  where n'' is equal to n plus the number of additional years of reserves life due to new discoveries and n'-1 is the life expectancy at the end of the year one under the assumption of constant unit resource rent (R_t), constant extraction rate and no volume changes;

- *the difference in the extraction path* (in physical terms): the present value at the beginning of time t is calculated assuming that the extraction rate in all the years after t-1 will remain constant. However, the actual quantity extracted in year t will normally differ from the quantity extracted in year t-1 and this change generates a change in the life expectancy:

Change in extraction rate = (n'/n) * $PV^{n,Rt}$ - $PV^{n'Rt}$

- *the change in the unit resource rent* between year t and year t-1. The conceptual issues are the same as for the change in the extraction rate described above. This element represents the change in the real unit rent during the period (a separate element, calculated as the opening stock multiplied by the GDP deflator, needs to be determined if the balance sheet is to be shown in current prices):

Change in unit resource rent in constant prices = PV^{nRt-1} * ($1-r_t/r_{t-1}$)

5.2 These elements account for the total change in the estimated present value of each natural asset (in constant prices), but it is evident from the formulae that the value attributed to each element is in part a factor of the order in which the calculations are made. The precise value is therefore a little arbitrary. It should be noted that the first two elements (extraction and "time passing"), taken together, can be taken to represent the allowance for depletion, while the final element (the change in the unit rent) represents the nominal holding gains. It should also be noted that this estimate of depletion is not dependent upon the relative scarcity of the resource within the UK (except insofar as that is reflected in the sale price). Further work is underway within the international community to develop measures which may provide an acceptable alternative basis for calculating the cost of depletion.

5.3 We now have the underlying framework for calculating the basic balance shhets in both physical and monetary terms. Table 10 shows how estimates of the stock of reserves of oil and gas, as defined in paragraph 2.4 above, have changed over time in terms of physical quantities:

Table 10

Physical balance sheet

Oil (million tonnes)

Expected level of remaining reserves, end year	1990	1991	1992	1993	1994	1995	1996	1997	1998
Opening stocks	1730	1695	1770	1895	1965	1975	1750	1640	1675
Extraction	-92	-91	-94	-100	-127	-130	-130	-128	-133
Other volume changes	57	166	219	170	137	-95	20	163	-7
Closing stocks	1695	1770	1895	1965	1975	1750	1640	1675	1535
Life expectancy in years	18	19	20	20	16	13	13	13	12

Gas (billion cubic metres)

Expected level of remaining reserves, end year	1990	1991	1992	1993	1994	1995	1996	1997	1998
Opening stock	1395	1480	1495	1620	1735	1945	1875	1860	1885
Extraction	-49	-55	-56	-65	-70	-75	-90	-92	-96
Other volume changes	134	70	181	180	280	5	75	117	-9
Closing stock	1480	1495	1620	1735	1945	1875	1860	1885	1780
Life expectancy in years	30	27	29	27	28	25	21	21	19

Life expectancy is calculated by dividing closing stocks by extraction in the year, ie it assumes constant future extraction rates.

5.4 Table 11 shows the monetary balance sheet for the natural assets of oil and gas for 1998, in current prices, on the basis of the expected levels of reserves at the beginning and end of the year, an 8% return on capital, a 4% social discount rate and an assumed constant total resource rent (ie constant real unit resource rent and constant levels of extraction), with no decommissioning costs. Figures for 1990 to 1998 are given in Annex D.

Table 11

Monetary balance sheet, 1998

(Using basic assumptions of constant total rent and no decommissioning costs)

£million, current prices

	Oil	Gas
Opening stocks 01/01/1998	**34,628**	**31,370**
Extraction	-974	-2,706
Time passing	380	1,457
Other volume changes	-34	-125
Change in extraction path	-262	-983
Change in unit resource rent (revaluation)	-25768	5,213
Other changes in price (inflation)	912	826
Closing stocks 31/12/1998	**8,884**	**35,052**

5.5 As discussed in paragraph 4.17, the ONS preference is to calculate a balance sheet on the assumption that the extraction rate decreases over time and that future unit rents are the average of the two latest years, taking into account estimated decommissioning costs. The calculation of a full balance sheet under these more sophisticated assumptions is more complex and will require further research. It is, however, relatively straightforward to calculate a summary balance sheet, comprising the first element (extraction) of the standard balance sheet set out above, and a residual which represents the remaining elements; the effect on the value of changes in the estimate of decommissioning costs is incorporated into the extraction estimate. The balance sheet shown in Table 12 is based on a present value for the start of 1998 assuming that production continues at the 1997 level for 5 years and then reduces by a constant absolute amount each year, while the value at the end of 1998 assumes 1998 production levels for 4 years before a steady decline. Decommissioning costs are assumed to be £16 billion (in 1998 prices):

Table 12

Summary monetary balance sheet, 1998

(Using preferred package of assumptions about future extraction rates, unit rents and decommissioning costs)

£ million, current prices

	Oil	Gas
Opening stocks 01/01/1998	**38,757**	**29,719**
Extraction, net of decommissioning contribution	2,250	2,486
Other changes (residual)	-16,580	3,179
Closing stocks 31/12/1998	**19,927**	**30,411**

6 The ownership issue

6.1 In this section we attempt to attribute the value of the subsoil asset to each sector involved in the extraction process according to the appropriation of the resource rent. The Government component is represented by royalties and all specific taxes on extraction, while the producer component is in theory derivable by subtracting the Government component from the total resource rent. The UKCS is, in fact, owned by the Government, but oil and gas companies are granted licences to extract the resources. It is widely acknowledged that these licences do not capture anything like the majority of the resource rent and as a result the extraction process has been subject to an increasingly complex system of specific taxes which have had a differing impact on the oil and gas industry over time. It therefore appears likely that the Government has taken a different share of the resource rent over time. It is possible to make an assessment of this share by comparing the total resource rent with the revenues received by the Government through taxes and royalties as shown in Table 13.

Table 13

Notional shares of estimated total resource rent for both oil and gas, assuming an 8% return on capital, no decommissioning costs

£ million current prices

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Government revenues	2,660	1,632	1,544	1,536	1,770	2,402	3,502	3,630	3,650
Oil & Gas companies	-1,355	-992	-977	23	1,675	2,490	4,363	2,030	29

Source: The Energy Report, 1998; ONS

6.2 From Table 13 we can see that oil and gas companies in general received a substantial portion of the estimated resource rent during the latter part of the 1990s, at least up to 1998. Taxes and royalties paid in any particular year may not be directly related to the sales made in that year, but even if they are averaged in some way over a longer period it seems clear that (on the assumption of an 8% return on capital) not all of the resource rent is being appropriated by the Government.

6.3 The picture for the late 1990s does not change significantly even if the rate of return on capital is assumed to be higher, at 10%. Under this assumption, however, the total rent drops and therefore over the 1990s as a whole taxes and royalties broadly equal estimated resource rents. For the reasons given in paragraphs 3.7 to 3.10 we do not think there are sufficient grounds for assuming a rate of return on capital higher than 8%.

6.4 The weakness of the figures for any individual year, and the evidence that over time some of the resource rent is being appropriated by the extraction companies, argues against the use of tax and royalty revenues in isolation as an indicator of resource rent and hence as a basis for the calculation of the present value of the reserves. Nevertheless in Table 14 we have calculated the present value of the oil and gas reserves on the assumption that the resource rent is fully represented by the specific taxes and royalties imposed by the Government. As Government revenues are not separately attributed to the oil and gas sectors, they have been split *pro rata* to the proportion of revenues.

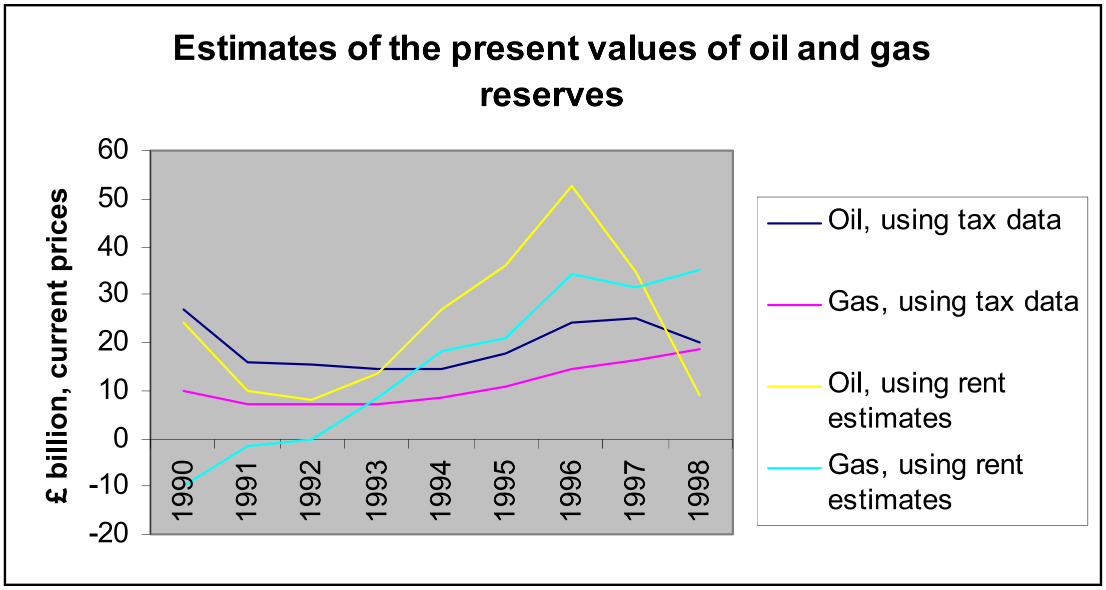
Table 14

Present value of oil and gas reserves in current prices at end of year, assuming future unit rents equal to the latest unit tax and royalty receipts and constant future extraction rates

£ million, current prices

Present value, end year	Oil	Gas
1990	18,704	6,886
1991	12,468	5,749
1992	13,172	6,332
1993	13,386	6,664
1994	13,637	8,038
1995	17,545	10,525
1996	25,551	15,262
1997	28,132	18,467
1998	20,048	18,819

6.5 The present values calculated under this assumption generate a smoother path over time than do values based on the estimated resource rent (using the assumption that future unit rents are equal to the latest unit rent), as we can see from the graph below. It seems likely that a similar effect, but with higher overall present values, would be evident if we calculated a series using the assumption that future rents are an average of the latest two years' unit resource rents.



6.6 The balance between the values of oil and gas is also quite different, because the calculation of the value using tax and royalty information is allocated to sectors using solely the relative revenue raised from oil and gas sales in each year.

7 Conclusions

7.1 In this note we have provided a valuation of the UKCS oil and gas reserves for all the years from 1990 to 1998 using a basic set of assumptions, and calculated a valuation specifically for 1998 based upon a preferred package of assumptions. Both sets of estimates have been used to develop alternative monetary balance sheets for the reserves for 1998.

7.2 The paper has demonstrated that it would be possible to put an upper and lower range on the valuations, using alternative sets of maximum and minimum assumptions, but more work is needed to determine the most plausible sets of assumptions in each case. In particular, it would be useful to investigate further alternative treatments of decommissioning costs and their sensitivity to different estimates of total costs and timing.

7.3 It would also be worthwhile developing a full balance sheet analysis for the preferred package of assumptions, although the algebra involved could be very complex and might need to be revised in the light of new international work on estimating depletion.

7.4 One area which needs further consideration is the linkage between estimates of unit rents, which are averages through the year, and stocks, which are estimates at points in time. This is of special concern where figures are shown in current prices, even though the underlying analysis has been carried out in constant prices. For this paper it has been assumed for simplicity that the unit rent for the year is equal to the unit rent at the end of the year, and that the opening stock in current prices is equal to the closing stock in the previous year's prices, but given the recent volatility of oil prices a more sophisticated assumption could give rise to significantly different estimates of value. It would also be worthwhile considering further whether the conversion of constant price figures into current prices is consistent with the use of real interest rates in the calculation of the return on capital.

7.5 Finally, more research would be helpful on the link between payments of specific taxes and royalties and the revenue from sales in any particular year. At the moment the relationship between receipts of taxes and sales revenues is not clear and it is not possible to make a meaningful allocation of the value of the oil and gas reserves between the Government and the extraction industries.

Acknowledgements

DTI

Planistat

Glossary [in a box?]

Specific taxes on extraction

Resource rent

Return on capital

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Office for National Statistics

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Estimates of oil and gas reserves 1990 to 1998

End year:	1990	1991	1992	1993	1994	1995	1996	1997	1998
Oil (million tonnes)									
Discovered reserves									
Proven	535	555	610	605	575	605	665	690	685
Probable	660	675	755	800	920	765	690	700	575
Possible	620	730	710	690	580	520	670	625	540
Range of undiscovered reserves									
Lower bound	500	540	530	560	480	380	285	285	275
Upper bound	3130	3395	3370	3355	3140	2920	2700	2680	2550
Range of total reserves									
Lower bound	1035	1095	1140	1165	1055	985	950	975	960
Upper bound	4945	5355	5445	5450	5215	4810	4725	4695	4350
Gas (billion cubic metres)									
Discovered reserves									
Proven	545	540	610	630	660	700	760	765	755
Probable	655	695	740	805	855	780	660	620	585
Possible	580	570	515	480	400	435	540	600	455
Range of undiscovered reserves									
Lower bound	280	260	270	300	430	395	440	500	440
Upper bound	1262	1252	1277	1297	1602	1412	1585	1700	1595
Range of total reserves									
Lower bound	825	800	880	930	1090	1095	1200	1265	1195
Upper bound	3042	3057	3142	3212	3517	3327	3545	3685	3390

Notes

The lower bound of the range of total reserves has been calculated as the sum of proven reserves and the lower bound of the range of undiscovered reserves.
The upper bound of the range of total reserves is the sum of proven, probable and possible reserves and the upper bound of the range of undiscovered reserves.
Expected reserves are the sum of proven reserves, probable reserves and the lower bound of the range of undiscovered reserves.

Basic data on costs, revenues and capital formation of the oil and gas sectors

£ million, current prices

	Total revenues		Operating costs		Development costs		Net capital stock		Capital consumption	
	Oil	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Oil	Gas
1980										
1981					2479	280				
1982					2304	607				
1983					1772	1054				
1984					1804	1248				
1985					1860	940				
1986					1761	630				
1987					1271	737				
1988					1454	728				
1989	8148	2380	1923	464	1749	950	23813	11579	3092	1503
1990	9440	2576	2347	591	2425	1135	24152	11837	3284	1610
1991	8802	3303	2695	665	3343	1735	24200	12263	3444	1745
1992	8828	3409	2647	722	3774	1600	25143	12195	3579	1736
1993	9794	4048	2922	785	3231	1340	26165	12191	3756	1750
1994	11353	4589	3082	824	2560	1060	27196	12336	3734	1694
1995	12784	5044	3107	867	2876	1433	28850	13287	3829	1763
1996	14783	6213	3124	885	2997	1329	29522	13483	3900	1781
1997	12844	6120	3153	1031	2934	1294	30592	13825	3794	1714
1998	10258	6781	3146	1153	3188	1865	30996	14754	3658	1742

Note: only those figures which have been used in calculations in this paper have been provided here.
Source: ONS

Estimates of total and unit resource rents in current and constant prices

This table shows the estimates of total and unit rents for each year in monetary terms (£ million, current and 1995 prices) assuming an 8% return on capital and no decommissioning costs.

		1990	1991	1992	1993	1994	1995	1996	1997	1998
Total rent (£m, 1995 prices)	Oil	2,228	810	632	1,064	2,422	3,541	5,225	3,246	893
	Gas	-679	-97	-26	559	1,112	1,351	2,389	2,134	2,480
Total rent (£m, current prices)	Oil	1,876	728	591	1,022	2,361	3,541	5,397	3,450	974
	Gas	-572	-87	-24	537	1,084	1,351	2,468	2,269	2,706
Average Unit Rent (£/tonne and £/kcm, 1995 prices)	Oil	24	9	7	11	19	27	40	25	7
	Gas	-14	-2	0	9	16	18	27	23	26
Average Unit Rent (£/tonne and £/kcm, current prices)	Oil	20	8	6	10	19	27	42	27	7
	Gas	-12	-2	0	8	16	18	27	25	28

Monetary Balance Sheet for oil and gas reserves 1990 to 1998, assuming constant current unit rents, constant extraction rates, an 8% return on capital, a social discount rate of 4% and no decommissioning costs

Present value of oil reserves (£ million, current prices)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Opening stock	14,177	24,135	9,712	8,057	13,734	26,951	36,246	52,725	34,628
Extraction	-1,876	-728	-591	-1,022	-2,361	-3,541	-5,397	-3,450	-974
Time passing	979	377	308	536	1,074	1,587	2,217	1,363	380
Other volume changes	560	629	641	815	1,386	-1,469	493	2,644	-34
Change in extraction path	2,888	70	-184	-539	-4,862	-749	162	365	-262
Change in unit resource rent (revaluation)	6,319	-16,405	-2,218	5,662	17,780	12,775	17,810	-20,550	-25,768
Other changes in price (inflation)	1,088	1,634	389	224	200	691	1,196	1,531	912
Closing stock	24,135	9,712	8,057	13,734	26,951	36,246	52,725	34,628	8,884

Present value of gas reserves (£ million, current prices)

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Opening stock*	-8,654	-9,923	-1,433	-412	8,688	18,050	21,029	34,267	31,370
Extraction	572	87	24	-537	-1,084	-1,351	-2,468	-2,269	-2,706
Time passing	-385	-57	-16	334	676	859	1,378	1,244	1,457
Other volume changes	-495	-39	-26	541	1,546	36	911	1,297	-125
Change in extraction path	975	92	4	-766	-634	-1,010	-3,963	-404	-983
Change in unit resource rent (revaluation)	-1,273	9,077	1,093	9,538	8,731	3,981	16,685	-3,760	5,213
Other changes in price (inflation)	-664	-672	-57	-11	127	463	694	995	826
Closing stock*	-9,923	-1,433	-412	8,688	18,050	21,029	34,267	31,370	35,052

* Strictly speaking, natural resources cannot have negative values; they have been shown as such in order to allow a full understanding of what the data reveals.