

North Sea oil and gas

An article in the March 1982 Bulletin⁽¹⁾ discussed the development and exploitation of oil and gas reserves in the North Sea⁽²⁾ and examined the implications for the UK onshore economy. After a gap of almost five years, the present article⁽³⁾ updates and modifies the earlier analysis. Developments up to the end of 1985 are compared with what was expected at the time of the previous article and some illustrative projections are made as to possible developments in the years ahead. Some macroeconomic implications of the North Sea endowment and of changes in oil prices are briefly considered. The Bank is grateful to Wood Mackenzie & Co for providing a number of projections and calculations.⁽⁴⁾

The course of oil and gas production

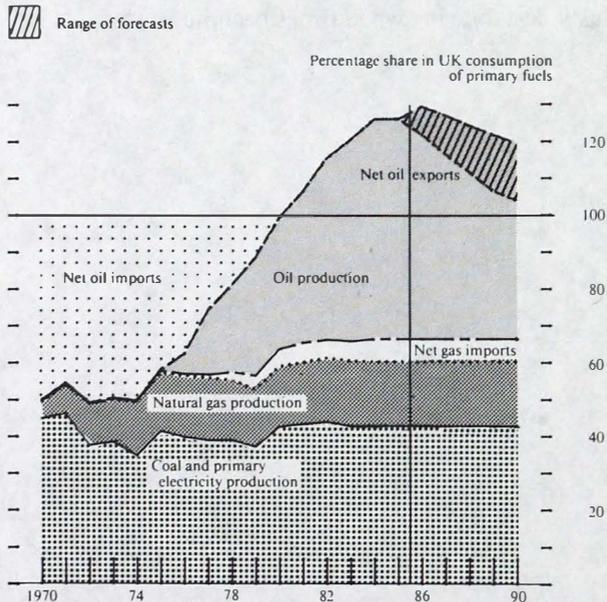
The importance of North Sea production for the United Kingdom may be illustrated by examining trends in the shares of different fuels in UK energy consumption and trends in UK production. Chart 1 shows the dramatic rise in production of indigenous oil and gas in the last fifteen years, from 5% of UK consumption of fuels in 1970 to 60% by 1981, with a further rise to around 80% by 1985.⁽⁵⁾

With coal and 'primary' electricity production (from hydro and nuclear sources) together amounting to about 45% of UK energy consumption, oil production equal to around 25% of UK energy consumption was available for export in 1985—roughly in the centre of the range

suggested by the 1982 article. UK production is thought to have now reached a plateau and, although the future path is of course uncertain, official forecasts⁽⁶⁾ suggest a steady decline from now on. On the basis of these forecasts and imposing the illustrative and arbitrary assumptions of unchanged shares of different energy sources in consumption and zero growth in overall energy consumption, the United Kingdom would cease to be self-sufficient in oil sometime in the 1990s or beyond. The oil price is one of the factors which will determine the output profile. However, most of the production assumed in official forecasts (which run to 1990) comes from fields already in production or under development, and may not be greatly sensitive to price movements over quite a wide range because, although the average cost of production from these fields is fairly high,⁽⁷⁾ the marginal cost is very much lower: thus prices would have to fall to a very low level before a significant proportion of this production would be lost. By contrast, production from fields that are still to be found or developed is likely to be relatively more sensitive to the expected price path.

The position of natural gas is somewhat different. Natural gas was originally discovered in the Southern Basin of the North Sea in 1964; production rose to account for 5% of the United Kingdom's energy consumption by the early 1970s and around 15% by 1975. Since then the proportion of domestically produced gas in UK energy consumption has remained fairly constant although the share of natural gas has risen, and with it imports. The United Kingdom now imports around 25% of its gas needs, mainly from the Norwegian part of the Frigg field. Although official forecasts of gas production are not published, it is expected that the United Kingdom will increase domestic output in the next few years as output from the Frigg field declines. The proportion of domestic gas consumption covered by domestic production can therefore be expected to rise.

Chart 1
United Kingdom energy consumption^(a)



(1) March 1982 Bulletin, page 56. That article in turn expanded upon analysis in the then Governor's Ashridge Lecture, reproduced in the December 1980 Bulletin, page 449.

(2) Throughout this article 'North Sea' is used as shorthand for the entire UK continental shelf (UKCS) together with UK onshore fields.

(3) Prepared by T S T Key and A R Litter of the Bank's Economics Division.

(4) In particular, Wood Mackenzie & Co provided forecasts of costs and output on the basis of oil price and discount rate assumptions set by the Bank.

(5) Adjusted to exclude an exceptional element due to the miners' dispute.

(6) Given in a reply to a Parliamentary question on 17 March 1986.

(7) The latest estimate from the Department of Energy is that the average cost in fields under development will be \$18 per barrel (in 1985 prices and at the average 1985 £/\$ rate) compared with \$9 per barrel in fields already in production.

Although production of North Sea oil and gas is large in terms of UK needs, it amounted to only 3.8% of world production in 1985. Nonetheless, the United Kingdom was then the world's fifth largest producer of both oil and gas.

How big are the reserves?⁽¹⁾

By convention, in the United Kingdom estimated reserves from existing discoveries are split into three categories: proven, probable and possible. Proven reserves are defined as those which are, on the available evidence, deemed to have a better than 90% chance of being both technically and economically producible; probable reserves as those where that chance lies between 50% and 90%; and possible reserves as those where the chance is significant but less than 50%. Estimates therefore depend not only on geological and other technical conditions but also on economic factors. Given that much of the cost of producing from a North Sea field will have already been incurred before production starts, it is, as already noted, unlikely that proven reserves attributed to fields in production or under development will vary very much as a consequence of shifts in the oil price. Estimates of probable and possible reserves will, however, be more affected by changes in expected prices. Estimates of reserves in future discoveries are uncertain both because of their likely sensitivity to price and because of the geological uncertainties.

Latest official estimates of oil and gas reserves, published in May 1986 by the Department of Energy,⁽²⁾ are brought together in Table A. Although these refer to the position at the end of 1985 and do not, therefore, take explicit account of more recent falls in oil prices, they cover a wide range of possible technical and economic conditions and provide a broad indication of probable ultimate remaining potential. Even so, the bounds should not be considered the absolute maximum and minimum of possibilities. The most likely outcomes are thought to be in the lower halves of the ranges given. For oil, the lower limit of 750 mt⁽³⁾ (ten years of current UK consumption)⁽⁴⁾ comprises only proven reserves in existing discoveries,

Table A
Remaining oil and gas reserves

	UK reserves(a)			Number of years reserves at 1985 consumption rates(b)		
	In present discoveries		In future discoveries	United Kingdom(a)	United Kingdom(c)	World(c)
	Proven	Probable	Possible			
	Millions of tonnes (oil equivalent for gas)					
Oil	750	480	650	295-2,235	750-4,115	10-58
Gas	540	495	644	183-696	540-2,375	11-49

(a) Department of Energy estimates for the end of 1985.

(b) Excluding exceptional element due to miners' dispute.

(c) Based on figures for 'proven' reserves in *Oil and Gas Journal*, 30 December 1985, which are on a different definition from those from the Department of Energy.

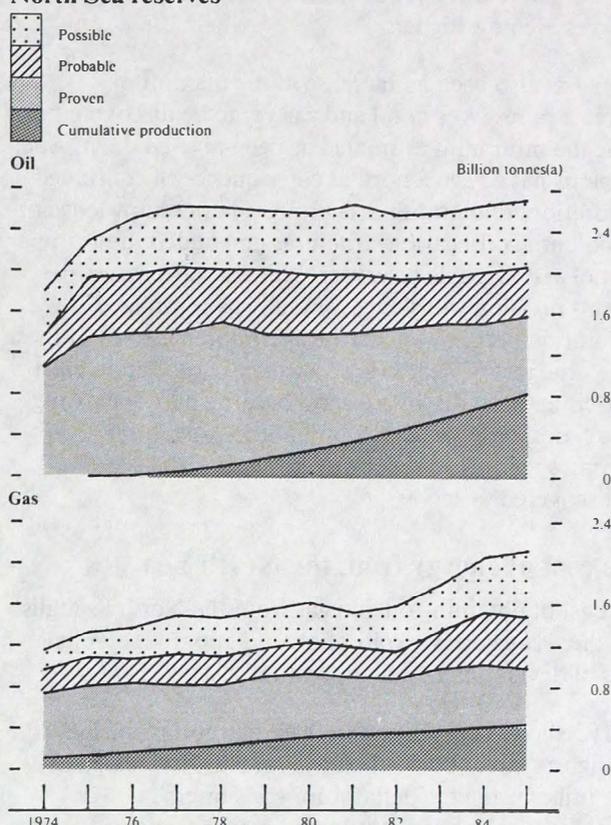
(1) Figures for reserves and production are exclusive of gas that has been flared or used on platforms.

(2) *Development of the oil and gas resources of the United Kingdom*. Department of Energy, 1986.

(3) mt = million tonne, and mtoe = million tonne of oil equivalent, using the Department of Energy's conversion factor—1 billion cubic metres of gas is equivalent to around 0.833 million tonnes of oil.

(4) At 1985 consumption rates excluding the exceptional element due to the miners' dispute.

Chart 2
North Sea reserves^(a)



(a) Official estimates. Original reserves from existing discoveries in licensed areas only. The dates shown are those when the estimates were made.
(b) Of oil or oil equivalent.

which are defined as virtually certain to be technically and economically producible. The upper limit includes 480mt (seven years consumption) of probable reserves, 650mt (nine years consumption) of possible reserves and up to 2235mt (thirty-two years consumption) of possible future discoveries both onshore and offshore. For gas the outlook is somewhat less conjectural, in that the upper figure for potential reserves in future discoveries is equivalent to only about 40% of remaining discovered reserves at end-1985; the corresponding figure for oil is almost 120%.

Chart 2 shows the changes that have occurred in official estimates of reserves of oil and gas in present discoveries over time. Between 1975 and 1980, estimates of proven reserves in both oil and gas fields changed little as real exploration expenditure (Chart 3) fell and few new discoveries were made. Between 1980 and 1985, however, exploration intensified, resulting in increases in proven reserves of 192 mt of oil and 73 mtoe of gas. Remaining proven reserves fell, however, as cumulative production of oil and gas between the two dates (562 mt of oil and 152 mtoe of gas) exceeded discoveries. Since 1980 there has been little change in the estimates of oil reserves in the categories 'probable' and 'possible', but there has been a

sharp rise in the case of gas reserves—more than enough to offset cumulative production so that even remaining reserves are now higher.

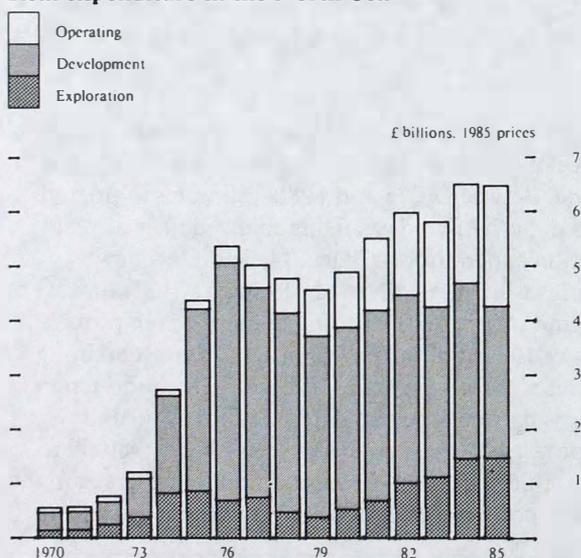
There has also been an increase in the maximum estimate of reserves of oil and gas yet to be discovered, while the minimum estimate has been revised down. Such revisions have been a normal consequence of continued exploration. Exploration has brought better knowledge of the potential oil-bearing structures and added to the upper limit of discoverable reserves, although this process of upward revision will slow eventually as completed exploration becomes increasingly comprehensive. At the same time reserves previously strongly expected to exist have either been discovered and become part of existing discoveries, or have been found not to exist, both outcomes tending to reduce the lower limit of 'undiscovered' reserves.

The cost of energy from the North Sea

The cost of obtaining oil and gas from the North Sea falls into three categories: exploration and appraisal; capital costs of development; and operating costs.

Chart 3 shows expenditure in these categories since 1970. The figures cover both oil and gas and are expressed at 1985 prices using the deflator for consumers' expenditure.⁽¹⁾ The sums involved have been large, amounting to the equivalent of 2.0% of GDP in 1980, rising to 2.2% in 1985 (or £6.5 billion in current prices). Although development was by far the largest element in 1980 (68% of the total), both exploration and operation grew strongly in recent years, pushing the share of development expenditure down to 43% in 1985. Exploration was encouraged by the relatively high oil price prevailing until about a year ago, by the higher price offered for new gas supplies by British Gas in the 1980s

Chart 3
Real expenditure in the North Sea



(1) As calculated by the Central Statistical Office. The same deflator is used to convert all current price values to 1985 prices in this article. Then, for example, the real cost of producing oil and gas is defined in terms of the volume of consumption that might otherwise have taken place for the same nominal outlay.

and by the substantial improvement in tax relief since the 1983 Budget. Meanwhile, however, as might be expected, it has become increasingly difficult to discover reserves in quantity. The average size of find per successful well has fallen sharply. Between 1964 and the end of 1980, 644 exploration wells were started resulting in 2563 mt of total possible 'discovered' oil reserves and 1596 mtoe of gas. Between 1980 and the end of 1985, a further 392 wells were started yielding only 147 mt and 529 mtoe respectively. Uncertainty over future oil prices since the sharp fall around the end of 1985 has dampened exploration activity more recently.

Valuing the North Sea endowment

The United Kingdom's reserves of oil and natural gas may (as any resource endowment) be regarded as a capital asset, part of the nation's wealth. An asset only has a value if it is capable of generating a positive stream of income or other utility. North Sea gas was being profitably exploited as early as the late 1960s; and, even before the 1973 price shock, some oil developments were seen as viable, on prevailing expectations of revenues and costs. The surge in prices in 1973 made it feasible to extract oil extensively at a resource cost unequivocally well below the ruling world price.

There are various ways in which oil and gas reserves might be valued. One would simply be the gross value (reserve volume multiplied by price), but this would ignore the very substantial costs involved in extracting the reserves and is for that reason not considered further. A more meaningful economic valuation would be the total value added—the value of output at the world market price less the cost of material and service inputs, or, equally, the sum of factor incomes generated to labour and capital. This would measure the scale of North Sea activity on the same basis as other components of national income, and is considered later. Finally, one could focus on the 'economic rent' accruing from oil and gas production, that is, the surplus of income arising, over and above all input costs including capital consumption and normal profits. This would be an appropriate indicator of the potential *addition* to national income provided by the oil and gas endowment, on the important assumption that there are no side-effects on the level of economic activity elsewhere in the UK economy and that the resources employed in its extraction would otherwise be fully employed in competitive activities elsewhere in the economy. The following paragraphs explore this approach. The implications of relaxing these important qualifying assumptions are discussed at a later stage.

Prices, costs and rents

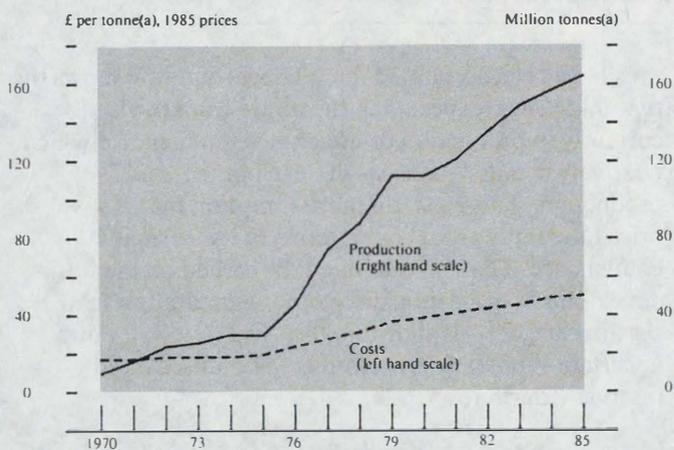
In the previous article, calculations were made which showed how North Sea oil becomes more expensive to produce as production shifts towards smaller, higher-cost

fields. For this article the calculation has been repeated for the oil fields included previously and extended to cover gas fields and the new fields that have since been or are being developed. The figures are now shown at 1985 rather than 1980 prices.

Conceptually, the calculation is straightforward. For each field, costs in a particular year are converted to 1985 prices by applying an appropriate index, and the present value of the resulting stream of costs is calculated by discounting or cumulating at an appropriate real discount rate. The production profile for each field is also converted to a single figure by applying the same discount rate, so that an estimate of real costs per tonne can be obtained for each field. By weighting together, for each year, the costs from different fields in proportion to their estimated production, a profile of aggregate costs per tonne in successive years emerges.

A practical problem, both here and elsewhere in this article, is the choice of a real discount rate. In the previous article a rate of 10% was chosen for the cost calculation, as being representative of the target real rates of return at which oil companies might be aiming, while a rate of 5%

Chart 4
Real cost of North Sea oil and gas



(a) Of oil or equivalent

was subsequently used for permanent income calculations (described later here), by reference to the required return on public sector investment programmes. In the present article a rate of 3% is used throughout. This is close to the average yield on index-linked gilts since their introduction in 1981. Although this yield may reflect the individual time preference of only a limited class of private savers, and so may not take into account the impact of one group's savings decisions on another's welfare, it is the most readily available indicator of risk-free time preference. Moreover, a rate of 3% is the same as, or close to that assumed in recent related work.⁽¹⁾

Chart 5
Real price and cost of North Sea oil

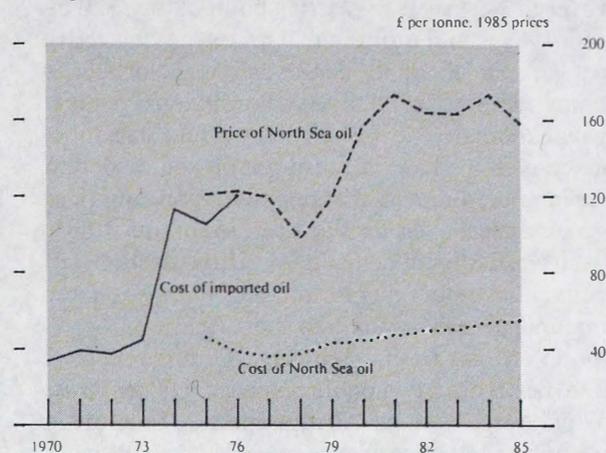


Chart 4 shows the results of these calculations for oil and gas together. In 1980, average costs in 1985 prices amounted to about £39 per tonne (about \$8 per barrel at an exchange rate of £1 = \$1.50); by 1985 this had risen to £50 (\$10). This bears out the result found last time, that production has been shifting towards higher-cost fields, and this trend is likely to continue. Since costs are incurred sooner, on balance, than output is produced, a higher discount rate would raise the present value of costs relative to that of output. Thus, for example, at a discount rate of 10% rather than 3% the costs in 1985 would be somewhat higher, at about £60 per tonne (\$12 per barrel).

Chart 5 compares the cost of North Sea oil with the price received and with the price of oil before the North Sea came on stream. With hindsight, it would not have been generally profitable to exploit North Sea oil at prices prevailing before the 1973 price shock, although gas, from low-cost fields in the southern North Sea, was being profitably produced in that period.

In the previous article the rent available from oil fields then in production or under development was calculated to be around £85 billion at 1980 prices, equivalent to around £119 billion at 1985 prices.⁽²⁾ For the purposes of this calculation it was assumed that the excess of the oil price (£157 per tonne in 1980 at 1985 prices) over the costs of extraction would rise at a compound rate equal to an appropriate discount rate (taken to be 5% in that instance) so that on these grounds at least the United Kingdom would be indifferent to the timing of oil production. The aggregate present value was, therefore, the value of production to date, plus that of estimated future production, less the costs of production, all expressed in constant prices.

The implied assumption of a rising real oil price has not of course been supported by experience in the intervening

(1) See M P Devereux and C N Morris 'North Sea oil taxation', Institute for Fiscal Studies, December 1983; and John Odling-Smee and Chris Riley 'Approaches to the PSBR', *National Institute Economic Review*, August 1985. Also, 3% is not far from the social rate of discount derived as the product of the expected growth of consumption per head (historically around 2½%) and the elasticity of the marginal utility of consumption with respect to consumption itself on the assumption that the latter is not much more than unity. The range of output and price projections used in the present exercise is assumed to represent uncertainty adequately. No special risk adjustment is therefore made to the rate of discount.

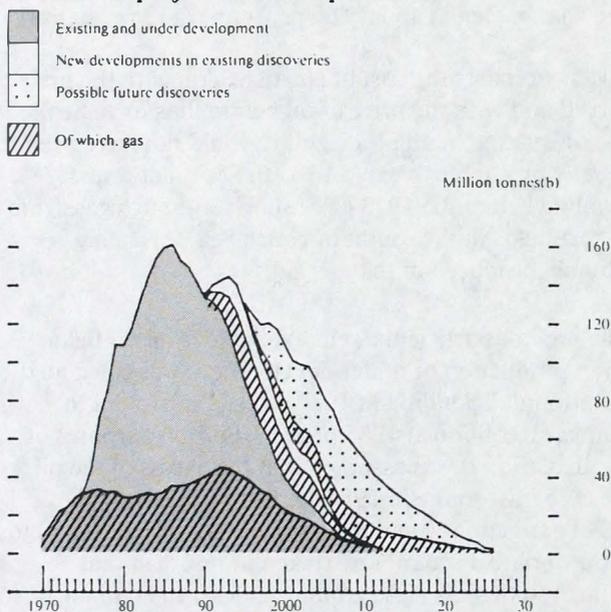
(2) To convert 1980 prices to 1985 prices on the basis of the consumers' expenditure deflator, multiply by 1.402.

years. Such an assumption would imply, even at a low discount rate of 3%, a doubling of the margin of price over costs every 23–24 years. A starting point of, say, \$20 per barrel in 1985 would result in real prices moving above \$50 per barrel in about 30 years even if real North Sea costs showed no rise at all. Even below that price it is likely that alternative forms of energy would start to replace conventional oil in consumption and moderate the rise in price, although that might not prevent prices rising above such levels for short periods of time (the low short-run elasticities of demand for oil and of supply of non-conventional fuel suggest that the oil price is likely to remain volatile in response to short-run supply disruption). In this article, estimates of future rent have therefore been calculated on three alternative *constant* real oil price assumptions. All are expressed in terms of 1985 prices; and an exchange rate of \$1.50 = £1 is assumed:

- (1) Constant £50 per tonne, \$10 per barrel
- (2) Constant £100 per tonne, \$20 per barrel
- (3) Constant £150 per tonne, \$30 per barrel

Chart 6 shows a projection of output if oil achieves the price of \$20 per barrel in the future.

Chart 6
Production projection at \$20 per barrel^(a)



(a) Projection by Wood Mackenzie & Co.

(b) Of oil or oil equivalent.

For each price assumption and related output profile, costs and revenues are expressed in 1985 prices and then discounted at the chosen discount rate of 3% per annum to produce present values. Subtracting the present value of costs from that of revenues gives an estimate of the present value of the rent. Table B gives the results according to different categories of field.⁽¹⁾ The first row

indicates that £73 billion of rent had been earned up to end-1985—the divide between past and future for this article. However, this calculation values gas at the price at which it was sold from the North Sea, whereas much of the rent from gas may be regarded as having been passed on to consumers in the form of prices lower than prevailing world equivalent energy prices (and to the government through the levy on Southern Basin gas fields and a higher current surplus than might otherwise have been earned by British Gas). Up to £38 billion of rent may

Table B
Illustrative calculations of present value of North Sea oil and gas^(a)

£ billions, 1985 prices

	Price assumption for future					
	£50/t, \$10pb		£100/t, \$20pb		£150/t, \$30pb	
Rent earned to end-1985	73	111	73	111	73	111
Rent in future from fields currently in production or under development	10		73		138	
Rent from future developments in existing discoveries	—		24		30	
Rent from future discoveries	—		44		74	
Total	83	121	214	252	315	353
<i>As percentage of 1985 GNP</i>	<i>27</i>	<i>40</i>	<i>70</i>	<i>82</i>	<i>103</i>	<i>115</i>

(a) Figures in *italics* show totals when past gas output is revalued to reflect its thermal equivalence to fuel oil. For the 'future' (ie from the beginning of 1986) gas is assumed to be priced in terms of this equivalence, with the additional assumption that the price of fuel oil relative to that of crude oil is the average from the past ten years.

thus have been accounted for.⁽²⁾ The second row shows the rent that can be expected in the future from fields currently in production or under development, for which relatively detailed forecasts of development and production plans exist, on the assumption that gas is priced the same as fuel oil in terms of its thermal equivalence. The rent that might be earned on the future development of existing discoveries—naturally a less certain category—is shown in the third row. Still more uncertain is possible rent from as yet undiscovered reserves (fourth row).

Resource flows and financing

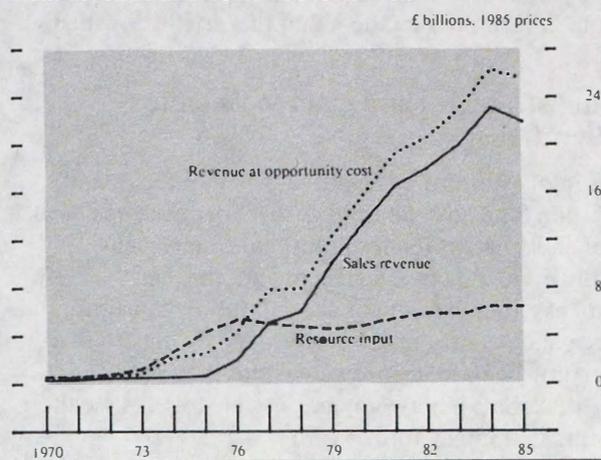
The cash flow associated with North Sea activities has been far from smooth, with large capital inputs required in the early years but even larger positive cash flows expected in later years. Chart 7 shows estimates of costs in terms of the overall resource input, and revenues, in constant prices. 'Sales revenue' represents the value of sales of North Sea oil and gas. The upper line, 'revenue at opportunity cost', indicates what revenues would have been, had gas been sold in the same quantities at prices equal to those of oil in terms of thermal equivalence. The chart indicates that revenues have exceeded costs on a year-by-year basis since 1977.

However, although North Sea activity may have been 'paying its way' in resource terms by the late 1970s, the

(1) Chart 6 and Table B are based on projections of costs and output provided by Wood Mackenzie & Co. The output projections imply reserve figures which lie within the range of official reserve projections shown in Table A.

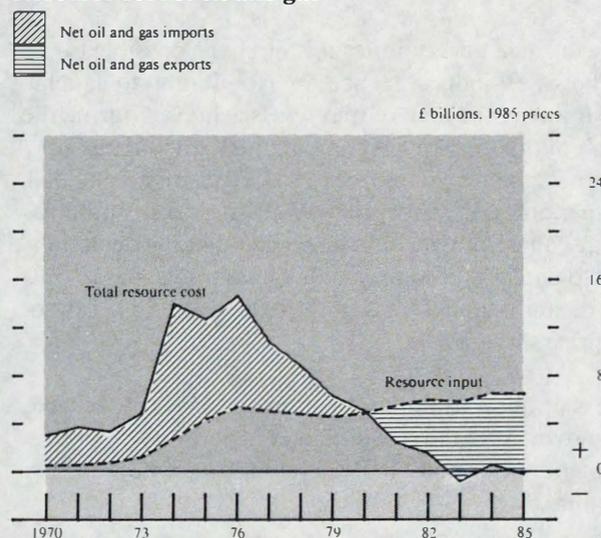
(2) Assuming that the price of an oil-equivalent tonne of gas would otherwise have been that of fuel oil.

Chart 7
Real revenue and costs in North Sea



United Kingdom was not yet self-sufficient in oil and gas, and net imports continued to impose a resource cost. The combined total of resource outlays in the North Sea and expenditure on net oil imports peaked at some 5% of GDP in 1976 (Chart 8). Self-sufficiency was achieved in 1980, and in 1983 export proceeds were sufficient on an annual basis to cover the full resource costs of the North Sea (ie including those incurred in satisfying domestic requirements). That the massive temporary rise in resources required during the 1970s did not necessitate cuts in resources devoted to other forms of consumption

Chart 8
Resource cost of oil and gas^(a)



(a) The total resource cost of oil and gas is the sum of spending on net imports of oil and gas and of spending on exploration, development and production in the North Sea.

and investment is explained by substantial recourse to world capital markets. Table C shows the overseas contribution to the development of the North Sea. Identified capital inflows associated with North Sea activity matched imports of inputs fairly closely both in the period up to 1980 and afterwards. These inflows result in subsequent flows of interest profits and dividends (IPD) abroad. If it is assumed that real resources are transferred abroad when IPD payments are made, it is

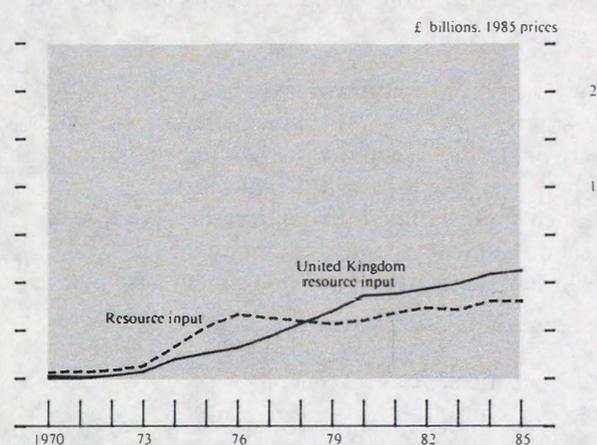
Table C
UK continental shelf: imports and overseas inward investment

£ millions	1970-79	1980	1981	1982	1983	1984
Imports of goods and net imports of services	5,350	622	925	1,143	987	933
Overseas investment	5,360	848	1,645	1,038	1,277	-41

Source: *United Kingdom Balance of Payments*, CSO. The CSO has now ceased publishing these series.

possible to derive the claim on UK resources represented directly by the North Sea. In the early 1970s it was the costs incurred in the North Sea less imports of goods and services for use there; throughout this decade it has comprised in addition a substantial element of IPD outflows. Chart 9 demonstrates how the use of capital markets postponed the demands of the North Sea on UK resources.

Chart 9
Real cost of the North Sea



Other direct economic consequences

In addition to the effects already noted, the development of the North Sea has had several other observable effects on the UK economy.

Table D presents the effects on the UK balance of payments at 1985 prices, so far as they can be identified. The first three lines simply show estimates of net export

Table D
The North Sea and the balance of payments

£ millions, 1985 prices	1980	1981	1982	1983	1984	1985
1 Domestic use of crude oil and gas	14,090	15,031	14,614	13,622	14,793	13,561
2 Production of crude oil and gas	13,323	16,584	17,810	20,012	23,027	21,485
3 Revenues from net exports of oil and gas (2-1)	-767	1,553	3,197	6,390	8,234	7,924
4 Direct investment from overseas in North Sea less imports of goods and services for UK continental shelf	317	906	-122	320	-1,025	—(a)
5 IPD outflow	2,891	2,711	2,815	3,222	3,209	3,569
6 Oil and gas balance (3+4-5)	-3,341	-252	260	3,489	4,000	4,355(a)
7 Notional balance of payments saving (2+4-5)	10,749	14,779	14,874	17,110	18,793	17,916(a)

(a) Bank estimate.

revenues as the difference between domestic production and consumption. Line 4 is the net of direct inward investment and imports for the UKCS (taken from Table C and converted to 1985 prices) and line 5 shows the IPD outflow. The net of these items (line 6) may be regarded as the overall identified balance arising from North Sea related transactions, but may be misleading since, for example, no account is taken of any diminution in outward investment by UK oil companies occasioned by the opening-up of domestic, North Sea opportunities. The notional balance of payments saving (line 7) is a calculation that takes full credit for the import-saving effect of indigenous supplies, but this notional series does not, of course, indicate how different the balance of payments might have been in the absence of the North Sea, because the remainder of the economy would in those circumstances have developed differently.

There are other direct economic effects: Table E shows the share of UK taxes, national income and investment accounted for by oil and gas, and the numbers employed offshore in the North Sea.

The North Sea's contribution to taxes has risen steadily—to 10.1% in 1985/86 on the definition shown. The share of North Sea activity in GDP has shown a similar path, rising to 6.3% in 1985; this is the value-added contribution, referred to earlier. Because of the direct investment income due abroad the share in GNP is lower. The share of fixed investment has fallen as

Table E
Direct contributions of North Sea oil and gas

	1975	1980	1985
Share of government revenue (per cent)(a)	—	5.6	10.1
Share of gross domestic product (per cent)(b)	—	4.4	6.3
Share of gross national product (per cent)(b)	—	3.4	5.1
Share of gross domestic fixed capital formation (per cent)(b)	6.5	5.7	4.7
Offshore employment (thousands)	6.0	22	29

(a) Royalties, petroleum revenue tax, corporation tax derived from North Sea activity, and the Gas Levy as a percentage of total direct and indirect tax revenues and national insurance contributions: financial years.

(b) At current prices.

the pace of new developments in the North Sea has slackened. Employment offshore in the North Sea has remained a negligible part of total UK employment, but there is likely to have been a much greater effect on onshore employment in related activities, for which definitive figures are not, however, available. The importance of the North Sea on these various measures can be expected to have diminished in 1986 as a result of the much lower oil price.

While these figures illustrate the significant position occupied by the oil and gas sector in the UK economy, they do not indicate what the overall economic impact of the North Sea endowment has been—eg whether and, if so, by how much the nation is better off than it might

otherwise have been—or whether the North Sea has been optimally exploited, if indeed an adequate yardstick is available. It is to these matters that this article now turns.

Optimal strategies and macroeconomic considerations

Two main questions may be posed: whether the rate of exploitation (and so depletion) of the North Sea has been optimal and whether the resultant rents have been optimally divided between current and, through investment either at home or abroad, future consumption. However, such questions are surrounded by uncertainty and can only be partially answered, and then only with hindsight. At best it may only be possible to rehearse the arguments that might apply.

The optimal depletion profile would, in a world free of risk and with perfect capital markets to permit those rents to be consumed at any chosen time, be that which simply maximised the present value of rents. This would in turn depend upon the pattern of prices and costs over the whole life of the North Sea, which are in practice, however, not known in advance, and upon the choice of discount rate. The maximisation would also in practice be constrained by technical factors limiting the pace of development or extraction, financial factors such as the need of oil companies to cover costs and service debts, and political or macroeconomic considerations such as a concern to prolong self-sufficiency in the face of uncertainty or a desire to avoid undue fluctuations in activity between different sectors.

Because of such uncertainties it is not even possible to assess how well-judged the pace of exploitation to date has been. However, the high output levels achieved during the first half of this decade, resulting in the United Kingdom being a net exporter of oil from 1981, evidently coincided with a period of, in retrospect, very high prices. With hindsight, therefore, it could be argued that the depletion profile to date has been reasonably favourable, but it would of course appear less so were there to be a renewed sharp price surge.

Whereas physical exploitation of oil and gas is observable, the deployment of the resulting rent is not. Any assessment in this domain is therefore still more conjectural.

The illustrative calculations presented above suggested that the present value at end-1985 of the past and future rents from oil and gas might lie anywhere in a range from £83 billion, or 27% of annual GNP, (assuming a future price of \$10 per barrel and without any addition for past low gas prices) to £353 billion, or 115% of GNP, (assuming \$30 per barrel and with an addition for past low gas prices). These figures may be compared with official estimates of the physical capital stock located in the United Kingdom at that date (ie buildings, plant and machinery) of £1,000 billion and of the United Kingdom's

external assets (net of external liabilities) of £80 billion.⁽¹⁾ If net North Sea rents earned up until the end of 1985 had all been saved, these could be regarded, along with the net present value of future expected rents, as a combined (albeit partly notional) asset, the yield from which should permit a level of consumption (private and public), from 1986 onwards, substantially above that feasible in the absence of North Sea oil. Assuming a rate of return equal to the assumed social rate of discount—3% per annum—a permanent annual addition to consumption, equivalent to anything from 0.8% to 3.5% of 1985 GNP, could be enjoyed.

Alternatively, a permanent increase in consumption could have been effected from an earlier date by spending part of the rents available to date or even by borrowing against the value of future expected rents, although, having started sooner, the available increment to annual consumption would, of course, be smaller. For example, this particular strategy might have begun in 1975. Assuming a real oil price from 1986 of \$10 per barrel, the permitted permanent annual rise in consumption from 1975 would have been 0.6% of 1985 GNP. Such a strategy would have required about two thirds of the rents earned up until the end of 1985 to have been saved. A future oil price of \$30 per barrel would have allowed a much larger permanent increase in annual consumption from 1975, some 2.5% of 1985 GNP. Under this strategy net borrowing of some £50 billion at 1985 prices would have been accumulated by the end of 1980. Thereafter, actual annual rents would have exceeded additional permitted annual consumption and net saving would first reduce outstanding borrowing and then accumulate net assets. The net accumulation of assets in all such cases would be such that when actual annual rents eventually fell to zero, the annual income from the addition to net non-oil assets accumulated to that date would equate to, and so exactly finance, the continuing permanent addition to consumption. It should be emphasised that in each case the calculated benefit is that of the North Sea endowment *given* the oil price as it has moved to date and is assumed to behave in the future. Although this benefit is greater the higher is the future oil price, this does not mean necessarily that the United Kingdom is better off with a higher price, because of costs which are likely to arise in importing fuels when indigenous supplies run down.

Such illustrative calculations assume implicitly, however, that any preferred allocation of rents could be achieved without side-effects on the rest of the economy. In practice such an assumption is unrealistic, so any assessment of the overall benefit of the North Sea becomes yet more clouded. The discussion moves away from the North Sea in isolation towards questions of macroeconomic performance. More specifically, how has the UK economy as a whole been influenced by its oil and gas endowment? The problem here is that one cannot know how the

economy would have performed in its absence, especially over a period of major upheaval in the world economy, with oil price shocks, a sharp inflationary surge followed by a fallback, and prolonged periods of slow or negative growth.

Detailed investigation of the effect of the North Sea on the United Kingdom's macroeconomic development over the past decade or so lies beyond the scope of this article. It is possible, however, to make a few general remarks.

Since 1975, when North Sea oil first came on stream, the UK current account has improved substantially, with a cumulative surplus of £20 billion in the period 1976–85, while identified net capital outflows have amounted to some £36 billion (the difference being accounted for by a positive balancing item, indicating an understatement of the current account surplus and/or an overstatement of net capital outflows). The estimated stock of net external assets rose from less than £3 billion to some £80 billion over the same period.⁽²⁾ It may be tempting to suggest that this increase represents the investment of North Sea rents and that its closeness to the present value of rents to date in Table B indicates that these rents have mainly been invested abroad. Quite apart from interpreting the illustrative calculations underlying Table B with too much precision and ignoring possible fortuitous changes in net external assets due to unanticipated valuation effects, such inferences would only be valid if, in the absence of North Sea oil and gas, the current (and hence capital) account of the balance of payments would have been in balance, and if domestic physical investment were unaffected directly or indirectly by the North Sea endowment. Neither condition can be assumed to have held.

It is often contended that the North Sea endowment was responsible for the sharp appreciation of sterling at the beginning of the 1980s, and can thus take credit for the subsequent reduction in inflation but must share, with supply-side rigidities, blame for the rise in unemployment. Once again, such statements cannot be substantiated without knowing what would have happened without indigenous oil. There is perhaps a tendency to overlook the fact that increases in the world oil price may be potentially inflationary even to an oil-endowed country like the United Kingdom, and to confuse the consequences of resultant disinflationary policy moves with those of the North Sea endowment of itself.

Implications of different oil prices

As noted already, the existence of indigenous oil and gas adds to national wealth provided the resource costs of production are lower than those of obtaining equivalent energy from other sources—as they have proved to be for

(1) From *United Kingdom National Accounts and United Kingdom Balance of Payments*, CSO, 1986. There are no statistics for other national assets such as other natural resources, consumer durables, human capital or works of art, which would be needed to make the comparison complete. The capital stock figure cited is on a net basis at current replacement cost.

(2) See also the article on the United Kingdom's external balance sheet in the September 1986 *Bulletin*, page 383, where, inter alia, valuation effects and rates of return are discussed.

the United Kingdom for a considerable period now. The North Sea endowment may therefore be judged unequivocally beneficial to the UK economy, in so far as additional welfare can be derived from the extra wealth. As has been illustrated, the value of the endowment is greater the higher is the assumed real price of oil. However, even if possible side-effects on the rest of the economy in terms of inflation or from any associated policy response were disregarded, this would not *necessarily* mean that the United Kingdom would be better off with a higher oil price, because developments after the United Kingdom ceased to be self-sufficient would have to be taken into account.

Although the United Kingdom is at present more than self-sufficient in oil and gas combined, the ratio of estimated remaining reserves to the current rate of consumption is lower for the United Kingdom than for the world as a whole (see Table A). Thus, at some point the United Kingdom is likely to resume as a net importer. A high price would then be to the nation's disadvantage. Whether the United Kingdom is better off today, in the present value sense, with a higher oil price than with a lower one depends upon whether the higher price is expected to endure, what social rate of discount is appropriate, and to what extent the profile of North Sea production, given the obvious technical and financial constraints, turns out to have been capable of adapting advantageously to price fluctuations. In addition, side effects on the rest of the economy would need to be considered. Clearly there is so much uncertainty here as to rule out any definite conclusion.

Conclusions

In the previous article, Department of Energy estimates were quoted for UK oil and gas reserves at end-1980.

These gave a range of 15 to 50 years consumption for oil, and 25 to 45 years consumption for gas. The comparable estimates in Table A for remaining reserves at end-1985—five years on—are 10 to 58 years for oil, and 11 to 49 years for gas.

The 1982 article suggested that the present value of economic rents from North Sea oil and gas might amount to 60%–120% of 1980 GNP. On this occasion different assumptions about the oil price and the appropriate rate of discount have been adopted, and a wider range of figures (Table B) emerges—from 27% to 115% of 1985 GNP. In principle this would optimally allow a permanent addition to consumption from 1975 onwards of anything from 0.6% to 2.5% of the 1985 level of national income (GNP) or, if all rents to date had been reflected in a net addition to national saving, a permanent increment from 1986 onwards of 0.8% to 3.5% of 1985 GNP. In practice it is impossible to discern how the rents already earned may have been deployed or anticipated rents pre-empted.

The North Sea sector is itself of considerable importance to the UK economy, having in 1985 contributed some 6% of GDP, but how economic performance as a whole has been affected by the discovery and exploitation of oil and gas is not clear, since one cannot know how the economy might otherwise have developed. The strength of the current account in recent years and the reduction in inflation probably owe something to the North Sea endowment. To the extent that the sluggishness of UK manufacturing over the past decade and the present high level of unemployment are consequences of oil-related developments, they are probably a reflection at least as much of high oil prices and associated disinflationary policy adjustments as of the exploitation of indigenous oil and gas reserves, although these influences are, of course, interrelated.