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Explanation of symbols

.	= data not available
*	= provisional figure
x	= publication prohibited (confidential figure)
–	= nil or less than half of unit concerned
–	= (between two figures) inclusive
0 (0,0)	= less than half of unit concerned
blank	= not applicable
2007–2008	= 2007 to 2008 inclusive
2007/2008	= average of 2007 up to and including 2008
2007/'08	= crop year, financial year, school year etc. beginning in 2007 and ending in 2008
2005/'06–2007/'08	= crop year, financial year, etc. 2005/'06 to 2007/'08 inclusive

Due to rounding, some totals may not correspond with the sum of the separate figures.

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Valuation of oil and gas reserves in the Netherlands - 1990-2005

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Summary:
This report presents the methods and results of compiling physical and monetary balance sheets of oil and gas reserves in the Netherlands for the period 1990-2005. The net present value method is used to discount expected future incomes, which are based on a physical extraction scenario and an expected resource rent. The resource rent is calculated as the gross operating surplus less the user cost of capital in the industry 'extraction of crude petroleum and natural gas.' Sensitivity analyses show that monetary values are relatively insensitive to changes in the physical extraction scenario, but extremely sensitive to the use of alternative discount rates and different valuation methods.

Keywords:
Monetary valuation, physical extraction, oil and gas reserves, net present value method, sensitivity analyses.

1. Introduction

This report presents the physical and monetary balance sheets of oil and gas reserves in the Netherlands for the years 1990 until 2005. Within the National Accounts, the compilation of physical and monetary balance sheets of oil and gas reserves has three main purposes. First, the results of this project will be used for measuring multi-factor productivity. Second, the results are published in the Dutch environmental accounts. Third, the balance sheets of oil and gas reserves will be a component of non-financial balance sheets.

Providing physical and monetary values to subsoil assets is essential for the measurement of multi-factor productivity (*mfp*) in mining and quarrying (Van den Bergen et al., 2007). Subsoil assets are important capital inputs, if not the most important input, in the production process of mining companies. If the extraction of subsoil assets is not considered a capital input, then changes in extracted subsoil assets will be reflected in *mfp* change. Including subsoil assets into the productivity calculations by considering them as capital inputs provides a better understanding of the production process and helps to provide meaningful interpretations of *mfp*.

Compiling physical and monetary balance sheets for subsoil assets is based on the premise that non-renewable assets have a finite capacity to supply materials. Taking depletion of subsoil assets into account provides a more complete view on the link

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between economic growth and environmental changes. The inclusion of subsoil asset accounts in the Dutch environmental accounts logically follows from this (SEEA, 2003).

The balance sheets of subsoil assets are also part of the non-financial balance sheets (SNA, 1993). Non-financial balance sheets present the market value of tangible and intangible (produced and non-produced) assets. The integration of subsoil assets in the non-financial balance sheets will provide a more complete view of the monetary value of non-financial assets in the Netherlands.

The monetary value of subsoil assets in the Netherlands is predominantly determined by natural gas reserves. In addition, a small fraction of subsoil assets in the Netherlands consists of oil reserves, coal reserves and other subsoil assets such as clay, sand, salt and gravel. The physical and monetary balance sheets in this report are restricted to oil and gas reserves. Other subsoil assets such as clay, sand, salt and gravel, are not yet included because their monetary value is relatively small. Coal reserves are not taken into account here because the extraction of coal currently does not take place in the Netherlands as it is economically unattractive.

This report is structured as follows. Section 2 describes the compilation of physical balance sheets for oil and gas reserves. Section 3 discusses the valuation method for constructing the monetary balance sheets. Section 4 presents the results of the monetary valuation of oil and gas reserves. Section 5 presents the sensitivity analyses for calculating monetary values. Section 6 describes how we would like to record the ownership of oil and gas reserves. Finally, Section 7 concludes the report with a summary and remaining issues that need to be resolved in future research.

2. Physical balance sheets

This section presents the physical balance sheets of oil and gas reserves in the Netherlands for the period between 1990 and 2005. First, subsection 2.1 explains how the physical reserves are classified. Then, subsection 2.2 describes how the physical balance sheets have been compiled.

2.1 Classification of physical oil and gas reserves

A number of methods exist for classifying the reserves of oil and natural gas. One example of such a method is the so-called McKelvey box which is discussed in the SEEA (SEEA, 2003; p.315). This classification system is based on the geological certainty and the economic feasibility with which oil and gas can be extracted. Although the classification in the McKelvey box seems intuitively clear, there is discussion on the guidelines for the various categories (London Group, 2007).

In the McKelvey box, a distinction is made between discovered and undiscovered reserves. In the category of the ‘discovered reserves’, an additional distinction is made between ‘proven’, ‘probable’, and ‘possible’ reserves. Proven reserves are defined as the volume of oil and natural gas in a reservoir that is estimated to be ultimately recoverable, with an expected probability of 90 percent that the reserve will prove to be larger than the predetermined level of the reserve.

In the Netherlands another category, called ‘expected reserves’, has been added to the classification. The category of expected reserves is equal to the sum of the two categories ‘proven reserves’ and ‘probable reserves’ (See figure 2.1). The expected reserve is the total volume of oil and natural gas in a reservoir that is estimated to be ultimately recoverable. It is the most realistic estimate available of the volume of the reserves. This volume is calculated on the basis of the mean values of geological parameters such as the shape and size of the oil and gas fields, saturation of the reservoir, and the type of sandstone or claystone in which the reservoir is found. Also available recovery techniques at the reporting date and economic conditions prevailing at that time are taken into account.

Figure 2-1: The McKelvey Box Resource Classification System

<table>
<tr><td rowspan="4">Commercial</td><td colspan="3">Discovered reserves</td><td colspan="2">Undiscovered reserves</td></tr>
<tr><td>Proven</td><td>Probable</td><td>Possible</td><td>Hypothetical</td><td>Speculative</td></tr>
<tr><td colspan="2">Expected</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="3">Reserves</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>Sub-commercial</td><td colspan="3">Resources</td></tr>
</table>

Source: SEEA (2003, p.316) adjusted for ‘expected reserves’.

The two main categories, ‘proven reserves’ and ‘expected reserves’ are quantified in the physical balance sheets for the Netherlands. Calculations for the monetary balance sheets are based on the ‘expected reserves’. Although the SNA 1993 recommends the use of proven reserves for compiling the monetary balance sheets, the concept of expected reserves is used here because it yields the most realistic estimate for the remaining reserves of recoverable oil and gas in the Netherlands. The ratio between proven reserves and expected reserves in the Netherlands is also large and relatively constant in time (close to 90 percent).

2.2 Compilation of physical balance sheets

The physical balance sheets consist of several items. Each year starts with an opening stock which is equal to the closing stock of the previous year. During the year the opening stock is altered by three annual flows: 1) reappraisal of existing reserves, 2) new discoveries, and 3) extractions. Theoretically, these items can be assessed for all different reserve categories. The combination of these items results in a physical balance sheet for oil and natural gas (Figure 2-2).

Figure 2-2: Conceptual balance sheet for mineral reserves

	Proven	Probable	Possible	Other	Total reserves
Opening stock					
Reappraisel due to					
- new information					
- new technology					
- price changes					
New discoveries					
Extractions					
Opening stock					

Source: SEEA, 2003, p.317.

The data required for compiling the physical balance sheets for oil and natural gas have been derived from the series of reports 'Oil and gas in the Netherlands, 1987 – 2007'. These reports are produced annually by TNO, the Netherlands Organisation of Applied Scientific Research, at the request of the Netherlands Ministry of Economic Affairs. To complete the data from the reports and to correct the data when necessary, TNO has been consulted extensively.

The volumes of oil and natural gas in the physical balance sheets are presented in terms of 'standard cubic meters', usually abbreviated as Sm^3. 'Standard' relates to the reference conditions: 15° C and 101.325 kPa (TNO / Ministry of Economic Affairs, 2007).

The physical balance sheets consist of three elements, the physical opening stocks, the different sources of annual alteration to physical stocks and the resulting closing stocks of physical reserves.[5] As discussed in subsection 2.1, the physical stocks in the Netherlands are determined following the two definitions of 'proven reserves' and 'expected reserves'. Accordingly, the physical balance sheets of oil and gas reserves have been compiled for the period between 1990 and 2005 (Figure 2-3, Figure 2-4, and Appendix 1).

Figure 2-3: Physical balance sheet of natural gas

Resource stock of natural gas	1990	1995	2000	2003	2004	2005
	Billion Sm^3					
Opening stock						
Remainder of proven reserve 1st January	1 725	1 845	1 714	1 567	1 482	1 445
Remainder of expected reserve 1st-January	1 865	1 997	1 836	1 689	1 615	1 572
Opening stock:	1 865	1 997	1 836	1 689	1 615	1 572
Reappraisal (gross) (+)	248	- 45	- 60	- 75	- 43	- 104
Reappraisal (net) (+):	248	- 45	- 59	- 75	- 43	- 104
New discoveries (+)	33	15	25	13	10	15
Re-evaluation of discovered resources (+)	287	18	- 17	- 19	25	- 46
Gross Extraction (at the expense of the reserve) (-)	72	78	68	69	78	73
Net Extraction (Gross including underground storage)	72	78	67	69	78	73
Other adjustments (= remainder)	0	0	0	1	0	42
Net closing stock (balanced via 'other adjustments')	2 113	1 952	1 777	1 615	1 572	1 510
Production from underground storage facility [1)]			- 0.7	0.4	0.4	- 0.1
Underground storage of natural gas: (-/- = net injection)			0.7	- 0.4	- 0.4	0.1
Injection			0.8	0.0	1.9	1.4
Production			0.1	0.4	2.3	1.3

1) In 1997 natural has been injected in one of the underground storage facilities for the first time.

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5 For the closing stock, the net closing stock is used, which means opening stock plus the 'net reappraisal'. This is the 'gross reappraisal', plus the amount of natural gas added to the underground storage facilities.

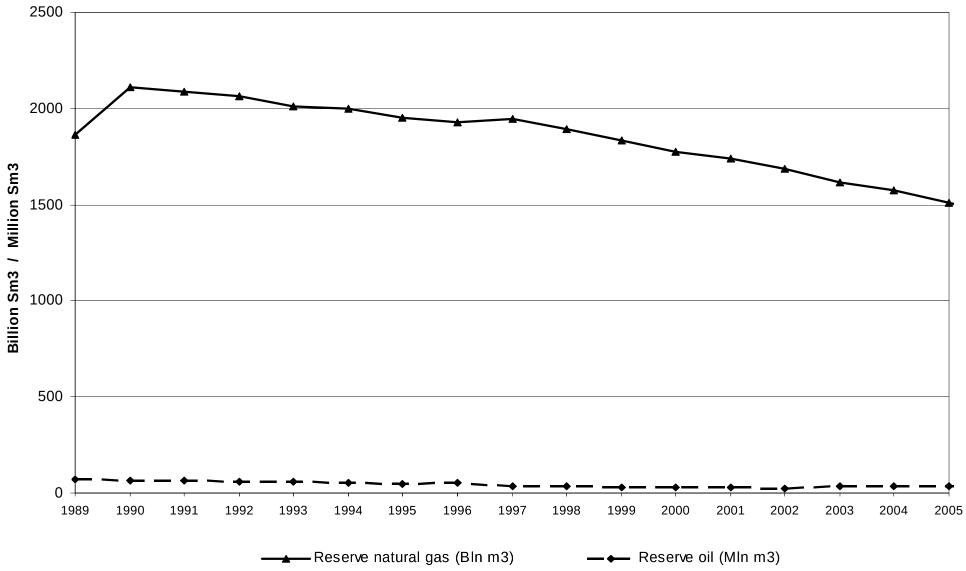
Figure 2-4: Physical balance sheet of oil

Resource stock of oil	1990	1995	2000	2003	2004	2005
	Million Sm ^{3}					
Opening stock						
Remainder of proven reserve 1^{st} January	25.0	17.0	15.0	9.0	.	.
Remainder of expected reserve 1^{st} January	68.0	56.0	32.0	26.0	38.0	34.0
Opening stock:	68.0	56.0	32.0	26.0	38.0	34.0
Reappraisal (gross) (+)	- 4.0	- 3.2	- 1.7	16.9	- 4.2	- 7.1
New discoveries (+)						
Re-evaluation of discovered resources (+)				19.6	- 1.7	- 5.3
Production / Extraction (-)	4.0	3.2	1.7	2.7	2.5	1.8
Other adjustments (= remainder)	0.0	- 2.8	- 0.3	- 4.9	0.2	9.0
Net closing stock (balanced via 'other adjustments')	64.0	50.0	30.0	38.0	34.0	35.9

1) For 2004 and 2005 the 'proven reserves' were not reported.

The result of the three distinguished annual flows (reappraisal, new discoveries, and extraction) determines the development of the physical stocks over time. The physical balance sheets clearly indicate a decrease of the remaining reserves in the Netherlands in the period between 1990 and 2005 (Figure 2-5).

Figure 2-5: Development of the expected Dutch oil and gas reserves



3. Monetary balance sheets

This section presents the method that is used to compile the monetary balance sheets for oil and gas reserves in the Netherlands. First, subsection 3.1 explains the valuation method and describes our assumptions on future physical extractions, the resource rent and the discount rate. Then, subsection 3.2 presents the individual items of the monetary balance sheet and explains how these items have been calculated.

3.1 Valuation method

The value of an asset in the national accounts should reflect the value that the asset would get if it were traded in an open market. Since observed market values for transactions in oil and gas reserves are not widely available, the net present value method is used to give a monetary value to the physical stocks of reserves. The net present value (NPV) method is used internationally and is recommended by the Handbook on Measuring Capital (OECD), the System of Environmental and Economic Accounting (SEEA) and the System of National Accounts (SNA) for the monetary valuation of subsoil assets.

The NPV method discounts the flow of future income (resource rent) from the extraction of oil and gas reserves by an appropriate discount rate. The future income flow is calculated by multiplying projected yearly physical extractions with the expected income per unit of the reserves (unit resource rent). For calculating the net present value, we assume that all yearly income from the extraction of oil and gas reserves is received at the end of the year.

The net present value of future income from the reserves at the beginning of year *t* is calculated as:

$$NPV^{t} = \sum_{\tau=t}^{\infty} \frac{RR_{t-1}^{\tau}}{(1+r)^{\tau-t+1}} = \sum_{\tau=t}^{\infty} \frac{rr_{t-1}^{\tau} Extr_{t-1}^{\tau}}{(1+r)^{\tau-t+1}} \quad (1)$$

Where,

RR_t^{τ} = resource rent in year τ as expected at the end of year *t*,

rr_t^{τ} = unit resource rent in year τ as expected at the end of year *t*,

$Extr_t^{\tau}$ = extraction in year τ as projected at the end of year *t*, and

$(1+r)^{\tau}$ = discount rate for discounting extractions in year τ to prices of year t.

3.1.1 Physical extraction scenarios

To calculate the monetary value of the remaining oil and gas reserves we have to make a projection of the future annual extraction of oil and gas. It is commonly expected that the level of annual extractions for oil and gas will decline when new finds no longer offset extractions and reserves are gradually exhausted. In the Netherlands, the cumulative production for oil and gas, which is the production since the start of exploitation, exceeded the remaining reserves more than ten years ago. As a result, future extractions may well be represented by a path of annually declining extractions. This is also in line with projections on the future extraction of oil and gas made by the Netherlands Ministery of Economic Affairs (TNO/Ministery of Economic Affairs, 2007). In the past, the path of physical extractions for natural gas has been slightly different as it has also been affected by governmental regulations.

The physical extraction scenario that was chosen for the extraction of natural gas contains two periods. The first period, until the year 2000, is characterised by a constant rate of extraction of 80 billion Sm^3 annually. This constant rate of extraction is based on governmental policies in this period prescribing a production boundary of 80 billion Sm^3 for natural gas and allowing only for small annual variations around this boundary.

Since 2001 the existing governmental policies came under discussion. The risk of gas fields getting depleted too soon, led to downward adjustments to the maximum threshold level of annual extraction. Given these reconsiderations, the physical extraction scenario contains a second period with a lineair decreasing rate of extraction since 2001. This lineair reduction is applied in such a way that, once the annual extraction has come to zero, remaining expected reserves will be exhausted. The starting values for the lineair reduction are determined as the average yearly extraction in the previous three years.

Contrary to the extraction of natural gas, the extraction of oil has not been restricted to a production boundary. The yearly extraction of oil was already decreasing before 2001. Therefore, the future extraction scenario for oil assumes a lineair reduction of the yearly extraction for all years. Similar to the extraction scenario for natural gas, the starting values for the lineair reduction are determined as the average yearly extraction in the previous three years.

3.1.2 Defining the resource rent

The resource rent (RR) is the net income from extraction defined as total revenue from sales less all costs incurred in the extraction process including user cost of produced capital. This means that the resource rent represents the returns from the resource only.

The resource rent is calculated by subtracting the user cost of produced capital from the gross operating surplus of the industry ‘extraction of crude petroleum and natural gas.’[6] Data on the gross operating surplus were derived from the Dutch system of national accounts. The user cost of produced capital are the cost of using produced capital assets during a year and comprises the revaluation of the assets, the opportunity cost of the money that is tied up in the assets, and the sum of all taxes-less-subsidies that the government levies on owning certain assets[7]. The user cost of produced capital are determined with an exogenous rate of return which equals the internal reference rate between banks[8] plus a risk premium of 1.5 percent.

To derive a resource rent that represents the returns from the resource only, the data had to be adjusted for the Dutch company ‘Gasunie’. This company is primarily involved in the distribution of natural gas, but has been included in the extraction industry for reasons of confidentiality. To calculate a resource rent for extraction only, its operating surplus and user cost of capital should be excluded from the

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[6] Excluding taxes on production, allocated to capital. Taxes on production must be excluded from the user cost of capital because taxes on production are also excluded from the gross operating surplus.

[7] See van den Bergen et al. (2007) for more details on calculating the user cost of capital.

[8] This is the interest rate that banks charge to other banks for borrowing money.

extraction industry. Data from the annual reports of the 'Gasunie' have been used for the adjustments of the gross operating surplus and the user cost of capital.

The compilation of individual balance sheets for oil and natural gas requires the calculation of a separate resource rent for oil and for natural gas. It was not possible, however, to make a clear distinction between the production costs of oil and gas. Therefore, the assumption was made that the ratio between the resource rents is equal to the ratio between the production values of oil and gas. Thus, we used the production values as weights to divide the resource rent between oil and gas. Then, the unit resource rent was calculated as the resource rent per standard cubic meter (Sm^3) of natural gas and oil equivalents.

3.1.3 *Expected resource rent*

Because the future income flows for calculating net present values are not known in advance we had to use an expected resource rent. The expected resource rent consists of a yearly projected extraction and a yearly expected unit resource rent. For the yearly projected extractions we used an extraction scenario (as explained in subsection 3.1.1). For the yearly expected unit resource rent we had to make an assumption on future price developments. Future price scenarios for oil and gas are often very unreliable, and expected trends have large uncertainties.

Because oil and gas prices fluctuate heavily, we decided to use a 3-years moving average to estimate the expected unit resource rent. By taking an average of the last three years, the monetary valuation of oil and gas reserves is less sensitive to yearly fluctuations of oil and gas prices. The 3-years average unit resource rent is calculated as:

$$rr^{t-2,t} = \frac{rr^{t-2} + rr^{t-1} + rr^{t}}{3} \qquad (2)$$

Where,

$rr^{t-2,t}$ = 3-years average unit resource rent, and

rr^{t} = unit resource rent in year *t*.

We made the assumption that expected unit resource rents are constant in real terms. We also assume that the unit resource rent in year τ as expected by the end of year *t*, as used in expression (1), is best estimated by the 3-years average unit resource rent as:

$$rr_t^{\tau} = rr^{t-2,t} \qquad (3)$$

3.1.4 *Discount rate*

The real discount rate that was used for calculating the net present value was set at 4 percent. This discount rate is similar to the real discount rate that is currently being used for fixed capital measurement in the Netherlands. The Netherlands Ministry of Finance also uses a real discount rate of 4 percent to discount future income of projects with a timespan of more than three years. We conducted several sensitivity analyses to investigate how the monetary value of oil and gas reserves is affected by different discount rates. The results of the analyses are presented in subsection 5.2.

3.2 Compilation of monetary balance sheets

The monetary balance sheets for oil and natural gas reserves were compiled with the valuation method that is described above. The monetary balance sheet for a single year starts with an opening stock value and ends with a closing stock value. Four items are distinguished between the opening stock and closing stock values: (1) revaluation due to price changes, (2) revaluation due to time passing, (2) extraction, and (4) other changes. The current subsection describes all items on the monetary balance sheets and explains how they are calculated.

3.2.1 Opening stock values

Opening stock values are calculated as the discounted values of the projected future extractions (for the current year and the years after, based on the physical reserves at the start of a year, until reserves are exhausted), times the expected unit resource rent. By substituting expression (3) into expression (1) the opening stock value of year *t* can be calculated as:

$$\text{Opening stock value } (t) = \sum_{\tau=t}^{\infty} \frac{rr^{t-3,t-1} Extr_{t-1}^{\tau}}{(1+r)^{\tau-t+1}} \qquad (4)$$

For example, the opening stock value in the year 1990 can be calculated as:

$$\text{Opening stock value}^{1990} = \sum_{\tau=1990}^{\infty} \frac{rr^{1987,1989} Extr_{1989}^{\tau}}{(1+r)^{\tau-1989}} \qquad (5)$$

3.2.2 Closing stock values

Closing stock values are calculated as the discounted values of the projected future extractions (for the following year and the years after, based on the physical reserves at the end of a year, until reserves are exhausted) times the average unit resource rent of the previous two years and the current year. The closing stock value of year *t* is equal to the opening stock value of year *t*+1 and can be calculated as:

$$\text{Closing stock value } (t) = \sum_{\tau=t+1}^{\infty} \frac{rr^{t-2,t} Extr_{t}^{\tau}}{(1+r)^{\tau-t}} \qquad (6)$$

The difference between the opening and closing stock values in year *t* is split into four components: (1) the first component is a revaluation due to price changes; (2) the second component is a revaluation due to time passing; (3) the third component is the monetary value of the yearly extraction; (4) the last component is a residual that accounts for other changes affecting asset levels and values, including discoveries, reappraisals and adjustments of mineral resources and differences between realized and projected physical extraction.

3.2.3 *Revaluation due to price changes*

The revaluation due to price changes is caused by an increase or a decrease of the unit resource rent. After revaluation, the monetary value is listed in end-year prices. Compared to the opening stock value, the revaluation uses a new expected resource rent which has moved one year ahead in time. All projected extractions are revalued with the new expected resource rent, except for the current year's projected extraction. As the resource rent for the current year is known at the end of the year, the projected extraction for the current year is revalued with the realized resource rent. Thus, the stock value after revaluation uses the realized resource rent of the current year for the valuation of the projected extraction in the current year, and the expected resource rent for the valuation of the projected extraction in the years after the current year. The stock value after revaluation due to price changes is therefore calculated as:

$$\text{Stock value after revaluation } (t) = rr^t \frac{Extr_{t-1}^t}{(1+r)} + \sum_{\tau=t+1}^{\infty} \frac{rr^{t-2,t} Extr_{t-1}^{\tau}}{(1+r)^{\tau-t+1}} \qquad (7)$$

3.2.4 *Revaluation due to time passing*

The revaluation due to time passing is caused by the fact that by the end of the reporting year the expected future incomes have come one year closer, and therefore these incomes should be discounted one year less. Thus, the monetary value of reserves increases as future income streams come closer. The stock value after revaluation due to time passing equals the stock value after revaluation times $(1 + r)$. Therefore, the stock value after revaluation due to time passing is calculated as:

Stock value after revaluation due to time passing (t) =

$$= rr^t Extr_{t-1}^t + \sum_{\tau=t+1}^{\infty} \frac{rr^{t-2,t} Extr_{t-1}^{\tau}}{(1+r)^{\tau-t}} \qquad (8)$$

3.2.5 *Valuation of extraction*

The monetary value of the yearly extraction equals the resource rent, which can also be written as the unit resource rent times the realized extraction. The stock value after extraction can be calculated by subtracting the resource rent from the stock value after revaluation due to time passing. In this way, the stock value after extraction is calculated as:

Stock value after extraction (t) =

$$= rr^t Extr_{t-1}^t + \sum_{\tau=t+1}^{\infty} \frac{rr^{t-2,t} Extr_{t-1}^{\tau}}{(1+r)^{\tau-t}} - rr^t Extr^t$$

$$= rr^t \left(Extr_{t-1}^t - Extr^t \right) + \sum_{\tau=t+1}^{\infty} \frac{rr^{t-2,t} Extr_{t-1}^{\tau}}{(1+r)^{\tau-t}} \qquad (9)$$

3.2.6 Other changes

The final component of the monetary balance sheet is a balancing item which contains the monetary value of the discoveries, reappraisals and adjustments of physical reserves, and the monetary value of differences between realized and projected physical extraction. This balancing item also contains changes in the extraction scenario. The monetary value of other changes can easily be found by subtracting the stock value after extraction from the closing stock value.

4. Results

The monetary balance sheets for oil and gas reserves in the Netherlands have been developed based on the net present value method, as described above, for the period 1990 until 2005. Figures 4-1 and 4-2 present a summary of the monetary balance sheets for natural gas and oil reserves. Balance sheets for all years under investigation can be found in appendix 2. Each balance sheet consists of an opening stock, revaluation due to price changes, revaluation due to time passing, extraction, other changes and a closing stock value.

Figure 4-1: Monetary balance sheets for natural gas reserves in the Netherlands

Monetary valuation of gas reserves	1990	1995	2000	2003	2004	2005
	mln euro					
Opening stocks 1-1	62 493	60 950	63 624	91 418	92 747	89 317
Revaluation	3 110	1 192	6 362	3 340	-2 806	14 005
Stock after revaluation	65 603	62 143	69 986	94 758	89 941	103 322
Revaluation due to time passing	2 624	2 486	2 799	3 790	3 598	4 133
Stock after revaluation due to time passing	68 227	64 628	72 786	98 548	93 539	107 454
Extraction	-4 483	-4 375	-5 708	-6 618	-7 579	-9 383
Stock after extraction	63 744	60 253	67 078	91 930	85 960	98 072
Other changes	5 491	489	-2 634	817	3 357	1 775
Closing stocks 31-12	69 236	60 742	64 444	92 747	89 317	99 846

Figure 4-2: Monetary balance sheets for oil reserves in the Netherlands

Monetary valuation of oil reserves	1990	1995	2000	2003	2004	2005
	mln euro					
Opening stocks 1-1	3 334	2 081	1 302	2 419	2 917	2 726
Revaluation	482	- 238	665	- 303	- 50	639
Stock after revaluation	3 816	1 842	1 968	2 117	2 867	3 365
Revaluation due to time passing	153	74	79	85	115	135
Stock after revaluation due to time passing	3 968	1 916	2 046	2 201	2 982	3 500
Extraction	- 386	- 174	- 254	- 283	- 305	- 321
Stock after extraction	3 582	1 742	1 792	1 919	2 677	3 178
Other changes	- 57	- 49	- 102	999	49	95
Closing stocks 31-12	3 525	1 692	1 690	2 917	2 726	3 273

Although we have used a 3-years average resource rent, the monetary value of oil and gas reserves remains sensitive to fluctuations in oil and gas prices. In the period under investigation, the monetary value of gas reserves varies between 60.7 billion euro and 99.8 billion euro. Moreover, due to price changes, the monetary value of oil and gas reserves has increased, whereas the physical amount of the reserves has decreased. This finding stresses, among others, the importance of looking at the physical balance sheets and the monetary balance sheets simultaneously.

By the end of 2005, the remaining gas reserves in the Netherlands had a monetary value of 99.8 billion euro. Remaining oil reserves were valued at 3.3 billion euro. Accordingly, including oil and gas reserves as non-financial assets in the National Accounts would increase the net-worth of the Netherlands by more than 100 billion euro in 2005.

5. Sensitivity analyses

The method for the monetary valuation of oil and gas reserves that was described in subsection 3.1 will be called the baseline model. To investigate the sensitivity of the baseline model to alternative assumptions, we conducted four different sensitivity analyses. The next subsections describe the results of these analyses. Subsection 5.1 compares the baseline model with three alternative physical extraction scenarios. Subsection 5.2 shows the sensitivity of the baseline model to the use of alternative discount rates. Subsection 5.3 shows the results for a different expected resource rent based on 1 year's unit resource rent. Subsection 5.4 compares the results of the baseline model with the outcomes based on the Hotelling alternative. Finally, subsection 5.5 compares the results of the baseline model with the government appropriation method.

5.1 Alternative physical extraction scenarios

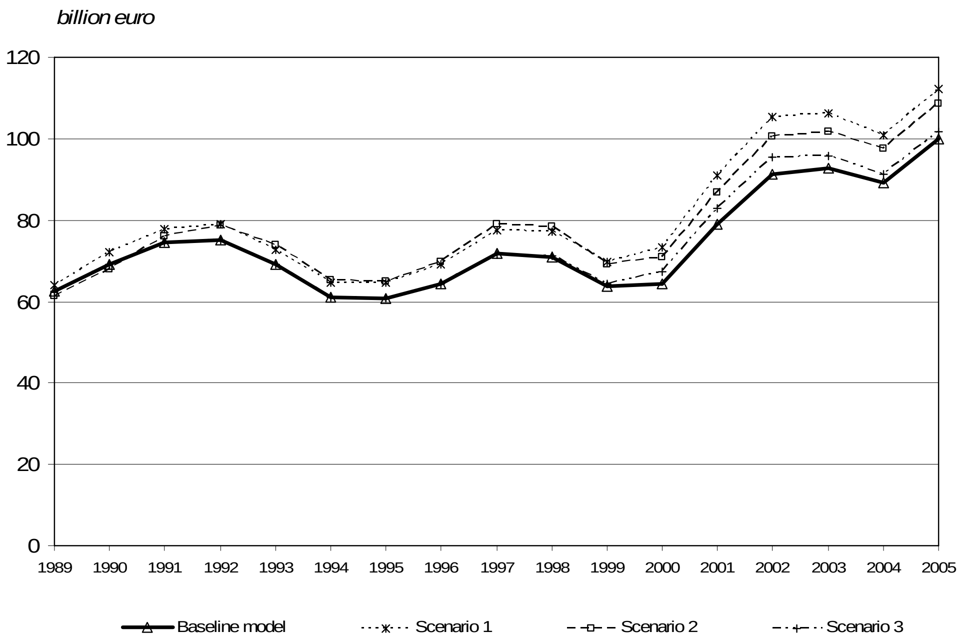
The amount and timing of projected future extractions has an impact on net present value. If projected future extractions are more distant in time, their net present value will be lower as they need to be discounted over a longer time period. To analyze the sensitivity of the net present value to different extraction paths, the baseline model was compared with three alternative physical extraction scenarios for oil and natural gas. The extraction scenarios vary by the level of annual extraction and by the rate of annual decline. The baseline model has a linearly decreasing physical extraction scenario. The alternative physical extraction scenarios for natural gas are described below:

- *Scenario 1* has a constant rate of extraction of natural gas of 80 billion m^3 annually, till the full expected reserve has been depleted.
- *Scenario 2* has a constant rate of extraction of natural gas that is equal to the average of the actual extraction in the last three years.

- *Scenario 3* is similar to the baseline scenario, with the restriction that the expected reserves must be depleted in 2040 at the latest. This causes a steeper decline of the reserves in the final years of extraction.

Figure 5-1 shows the sensitivity of the baseline model to these three alternative extraction scenarios for natural gas.

Figure 5-1: Closing stock values of gas reserves for alternative extraction scenarios

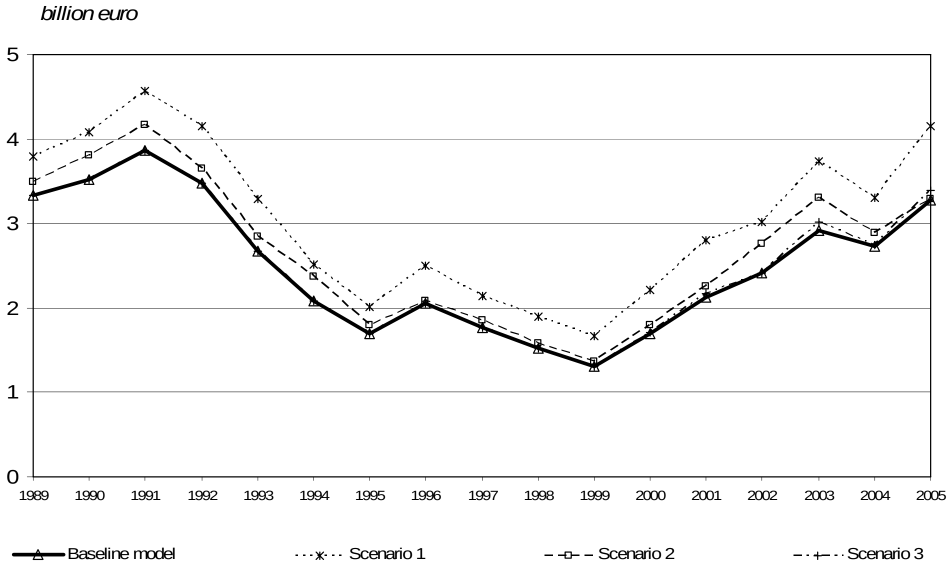


Since the extraction of oil has not been restricted to a production boundary, some physical extraction scenarios for oil are different from the extraction scenarios for natural gas. The physical extraction scenarios for oil are described below:

- *Scenario 1* for the projected future extraction of oil is based on an expected constant yearly extraction rate that equals the realized extraction of the previous year, until physical reserves are exhausted.
- *Scenario 2* for the projected future extraction of oil is based on an expected yearly constant extraction rate that equals the average realized yearly extraction of the previous three years, until physical reserves are exhausted.
- *Scenario 3* resembles the baseline scenario, with the restriction that remaining expected reserves are exhausted in 2030.

Figure 5-2 shows the sensitivity of the baseline model for the monetary valuation of oil reserves to the alternative physical extraction scenarios for oil.

Figure 5-2: Closing stock values of oil reserves for alternative extraction scenarios



From these sensitivity analyses it can be concluded that the differences between the monetary values of different physical extraction scenarios and the baseline model are relatively small for natural gas (<15 percent) and somewhat larger for oil (<25 percent). In contrast, taking the extreme unlikely scenario of an infinite lifetime of the reserves in which future extraction is fixed, the value of natural gas would be more than 2.3 and for oil nearly 2.5 times the value of the reserves in 2005.

Furthermore, it can be concluded that the baseline model provides the most conservative estimations of monetary values for both oil and gas reserves. This can be explained as the linearly decreasing extraction scheme in the baseline scenario results in the longest life-length of the reserves and therefore stretches the future incomes of the reserve over a longer time period. Discounting these future incomes results in a lower, and therefore more conservative, monetary value of the reserves.

5.2 Alternative discount rates

The baseline model was compared with 3 alternative models with real discount rates of 2 percent, 6 percent, and 10 percent, respectively. A different discount rate has an effect on the net present value of future incomes. Different discount rates reflect different time preferences and attitudes towards risk. A higher discount rate gives a lower weight to future resource rents. Therefore, the monetary value of oil and gas reserves is lower for a higher discount rate and higher for a lower discount rate. The results of the sensitivity analysis for the alternative discount rates are shown in figures 5-3 and 5-4. The average differences between the baseline model and the alternative models for natural gas are between 19 and 42 percent, and for oil between 15 percent and 36 percent. These findings demonstrate that the monetary valuations are extremely sensitive to changes of the discount rate.

Figure 5-3: Closing stock values of gas reserves for alternative discount rates

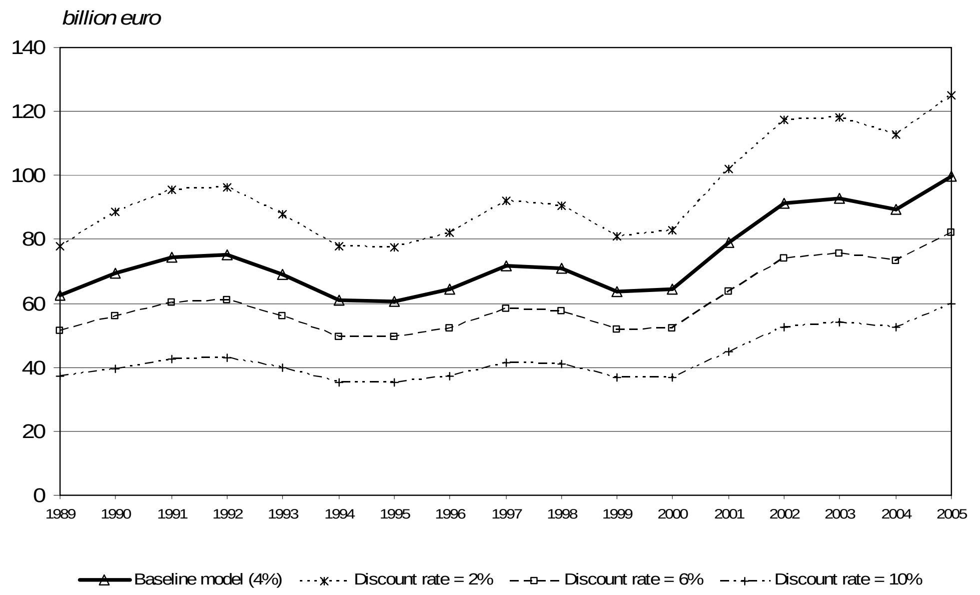
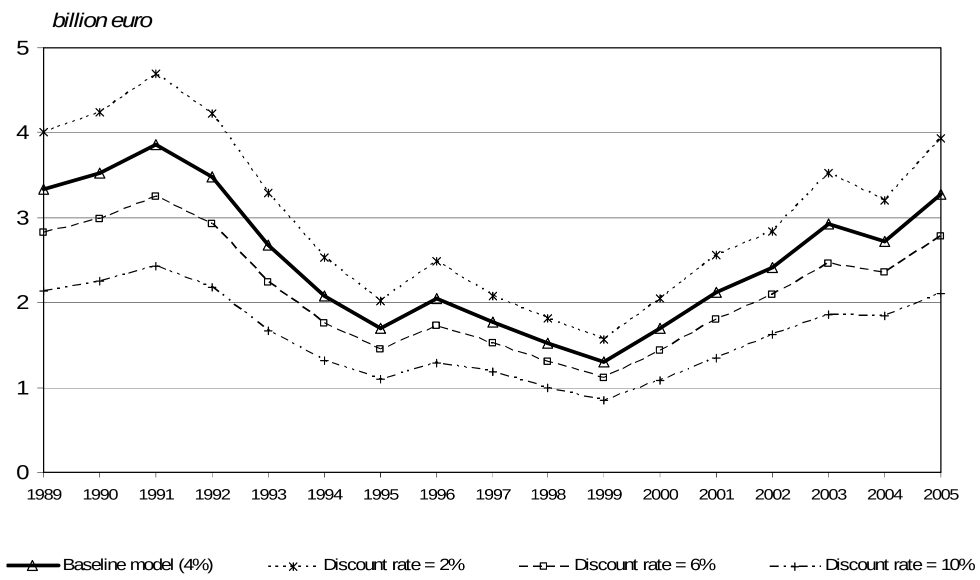


Figure 5-4: Closing stock values of oil reserves for alternative discount rates



5.3 Expected resource rent of 1-year versus 3-year

The baseline model with an expected resource rent based on a 3-years moving average was compared with an alternative model with an expected resource rent based on a one year's resource rent. Figures 5-5 and 5-6 present the findings of this analysis for gas reserves and oil reserves, respectively.

Figure 5-5: Closing stock values of gas reserves for 1-year versus 3-years resource rent

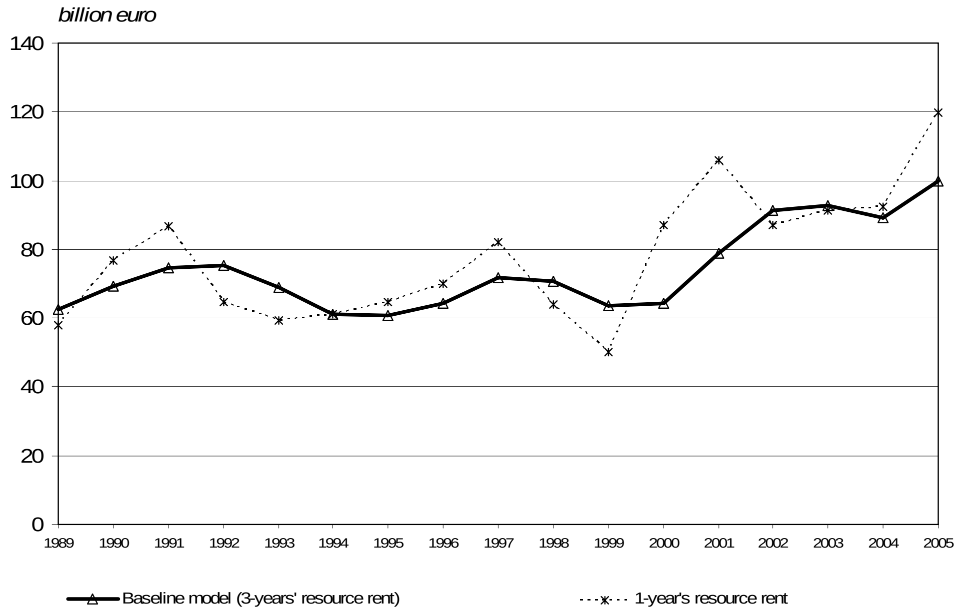
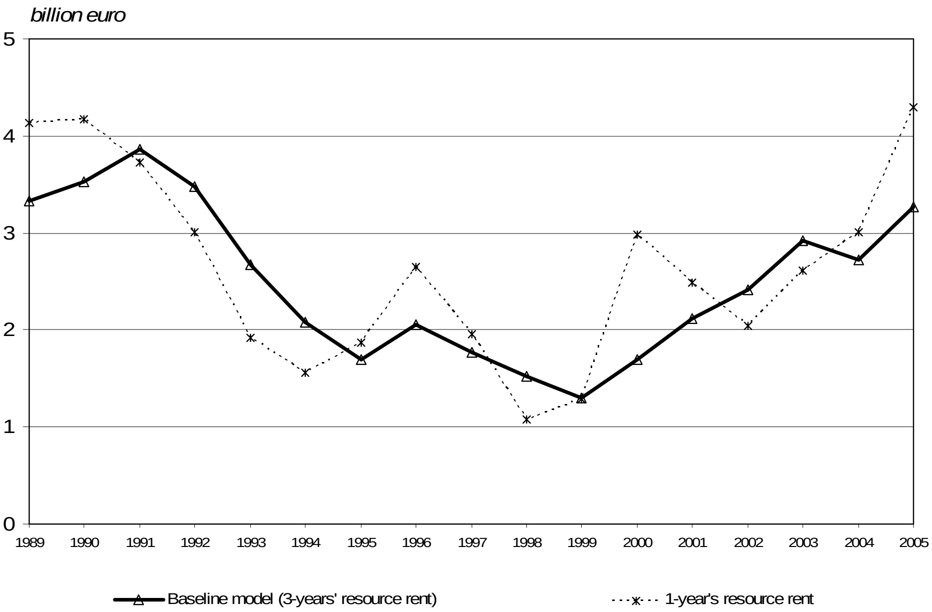


Figure 5-6: Closing stock values of oil reserves for 1-year versus 3-years resource rent



The figures indicate that the monetary valuation indeed becomes less sensitive to yearly fluctuations of oil and gas prices by taking a 3-years average resource rent. The yearly differences for gas reserves range from -13.4 billion euro to 27.1 billion euro. The monetary valuation based on a 1-year's resource rent on average would be nearly 5 percent higher than the baseline model in the period between 1990 and 2005. For oil reserves, the yearly differences range from -0.8 billion euro to 1.3 billion euro. The average monetary valuation of oil reserves in the period 1990-2005 based on a 1-year's resource rent would be more than 5 percent higher than the baseline model. Thus, the results of this sensitivity analysis also show that using a 3-years resource rent on average provides a more conservative monetary valuation than using a 1-year's resource rent in the period between 1990 and 2005. More importantly, the 3-years resource rent provides a more stable value of the reserves.

5.4 Hotelling alternative

The Hotelling alternative is a different way of calculating the net present value of natural resources (SEEA, 2003). The main assumption in the Hotelling alternative is that the unit resource rent increases over time at a rate equal to the nominal discount rate. The value of the stock of the resource, therefore, is independent of when it is extracted and is simply calculated as the 3-years average unit resource rent times the remaining units of the resource. The monetary valuation based on the Hotelling alternative is similar to valuation based on the assumption that all of the remaining reserves are extracted in the reporting year.

Figure 5-7: Closing stock values of gas reserves for Hotelling alternative

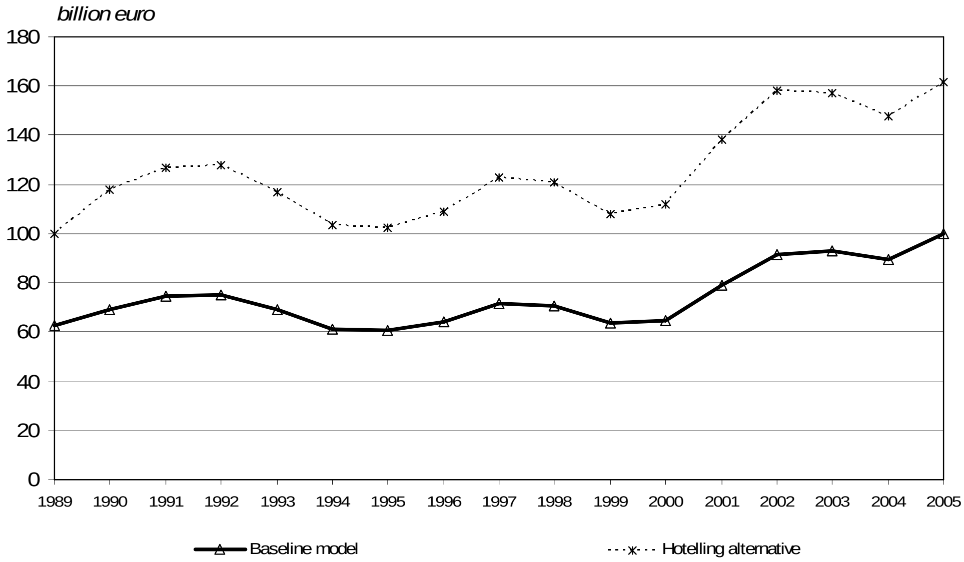
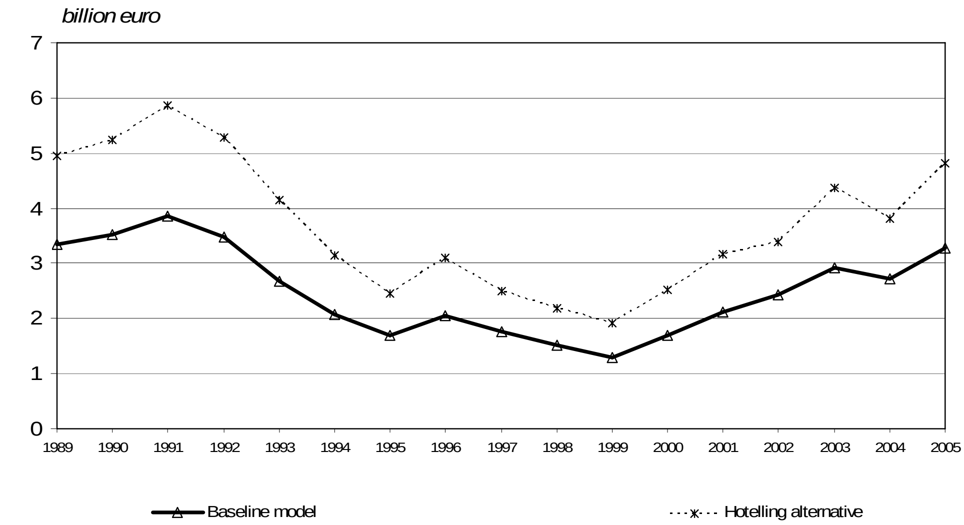


Figure 5-8: Closing stock values of oil reserves for Hotelling alternative



Figures 5-7 and 5-8 compare the monetary valuation according to the Hotelling alternative with the baseline model for natural gas and oil reserves respectively. It is shown that on average natural gasreserves are valued 69 percent higher, and oil reserves are valued 48 percent higher, based on the Hotelling alternative.

In the past 20 years, the Hotelling alternative led to higher estimates of the monetary value of mineral resources. Recent price increases, however, may change this notion. For future years, perhaps the Hotelling alternative provides a more realistic value.

5.5 Government appropriation method

In the recent past, Statistics Netherlands developed preliminary balance sheets for oil and gas reserves based on the government appropriation method (Pommée 1998, van den Berg and van de Ven 2001). In this approach, the expected revenues of the government related to the extraction of oil and gas were used as a proxy for the expected net future returns recommended in the 1993 SNA. Since the Dutch government attempts to appropriate most of the resource rent through royalties and taxes, this method performed reasonably well. Furthermore this method was easy to implement and did not put strong demands on the data.

Figure 5-9: Closing stock values of gas reserves for government appropriation method

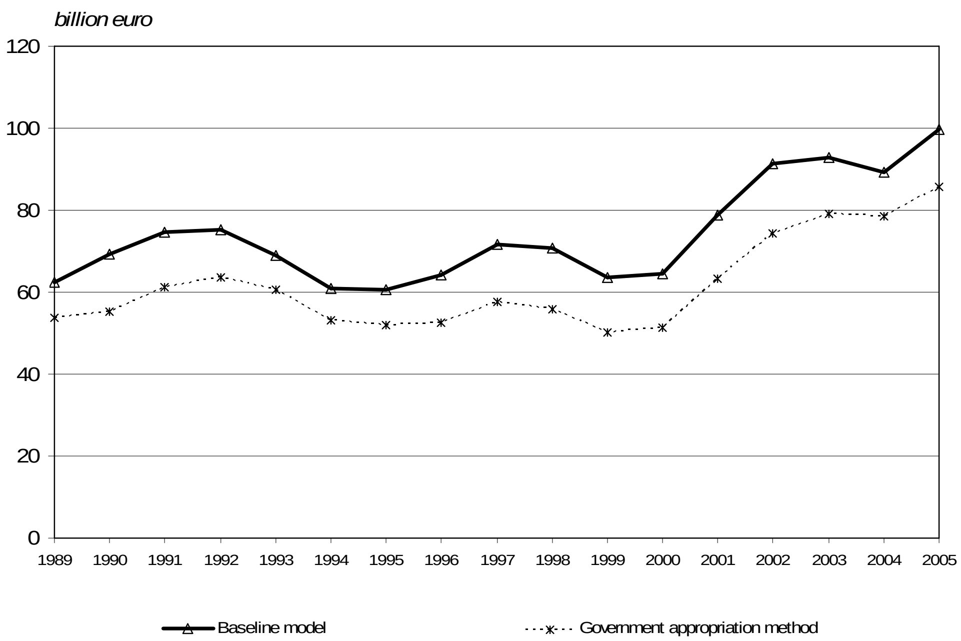


Figure 5-9 presents a comparison of the government appropriation method with the baseline model for natural gas. To calculate the monetary value according to the government appropriation method, we used the natural gas revenues (in Dutch 'aardgasbaten') from non-tax means and corporate taxes[9]. The unit resource rent was determined by dividing the yearly natural gas revenues by the physical extraction in the concerning year. Subsequently, the 3-years average unit resource

[9] It was not possible to split the revenues into natural gas revenues and revenues of other subsoil assets. It is assumed that all revenues are revenues from natural gas. In future research, we will investigate how the revenues can be split between natural gas and other subsoil assets.

rent for natural gas revenues was used to calculate the net present value for natural gas revenues based on the same physical extraction scenario as the baseline model.

The results show that the monetary valuation of gas reserves based on the government appropriation method is lower than the baseline model which has been derived from the industry's gross operating surplus. The average government take in the period between 1990 and 2005 is 83 percent; the remainder may be seen as a sort of subsidy to mining companies for their annual extraction.

6. Recording the ownership of oil and gas reserves

Recording the ownership of oil and gas reserves is neither an easy nor a straightforward task. In the Netherlands, and in many other countries, the legal owner of the reserves (government) is different from the extractors undertaking the development of the reserves (non-financial institutions). The economic ownership of the reserves is usually shared between the legal owner and the extractor. The extractor typically takes part of the economic ownership of the reserves through extractive licenses. The legal owner often appropriates the largest part of the economic benefits through royalties, other non-tax means and corporation taxes. As a consequence, neither the extractor nor the legal owner has exclusive ownership claims over the reserves. This complicates the sectoral allocation of oil and gas reserves.

Several options have been proposed for recording the ownership of oil and gas reserves (Comisari, 2007). A widely considered option is to record the reserves on the balance sheet of the legal owner with rental payments by the extractor to the legal owner. Although this option is relatively easy to implement, it may give an inappropriate view of the shared ownership of the reserves. In addition, depletion of reserves is not reflected in the accounts of the legal owner, but is charged to the production account of the extractor only.

As an alternative, we opt for a construction in which the ownership of oil and gas reserves is partitioned by using a financial lease arrangement (Comisari, 2007). The value of the resource rents arising during the period of the extractive license is attributed to the extractor, with the remainder of the reserve value attributed to the legal owner. A financial lease is imputed, equal to the value of expected rental payments (royalties, other non-tax means and corporation taxes) to the legal owner. Figure 6.1 presents how this option works out in practice for the Netherlands.

We assume that the exploitation concession remains with the extractor until the reserves are completely exhausted. Therefore, the entire value of the reserves is presented in the balance sheet of the extractors. Only that part of the resource rent that is appropriated by the government is presented as a financial asset / liability by the legal owner / extractors. This value equals the monetary value of gas reserves based on the government appropriation method. The resulting net balance sheet positions now provide the factual shared ownership between the legal owner and the extractor. Furthermore, this recording scheme allows that all balancing items in the current and capital accounts of the extractor can be adjusted for depletion, and thereby facilitates the measurement of multi-factor productivity.

Figure 6-1: Balance sheets for recording the ownership of natural gas reserves

Balance sheet 31/12 2005: legal owner (mln euro)

	Assets	Liabilities	
Loan, gas reserves	85743		

Balance sheet 31/12 2005: extractor (mln euro)

	Assets	Liabilities	
Gas reserves	99846	85743	Loan, gas reserves

7. Conclusions and future research

This report describes the methods and results of the physical and monetary balance sheets for oil and gas reserves in the Netherlands. Physical balance sheets were compiled based on the yearly reports 'Oil and gas in the Netherlands' by the Netherlands Ministry of Economic Affairs. Furthermore a physical scenario was developed to estimate future extractions from oil and gas reserves. This extraction scenario was used to calculate the monetary values for the monetary balance sheets.

The monetary values of oil and gas reserves in the Netherlands were calculated by using the net present value method to discount expected future income of oil and gas. The real discount rate was set at 4 percent. Future income was estimated based on a 3-years average resource rent and the physical scenario of future extractions. The resource rent was calculated by subtracting the user cost of produced capital from the gross operating surplus in the industry branch 'extraction of crude petroleum and natural gas'.

The applied method can be considered a conservative method as future extractions are valued based on historical prices for oil and gas as opposed to future price expectations. This also implies that potential future price increases, which have an upward effect on the valuation of natural resources, are not taken into account. Furthermore, the extraction scenario that was chosen, results in a lower monetary value than other extraction scenarios that were analysed. This is caused by the fact that in the current scenario future incomes are stretched over a longer life length.

The sensitivity analyses showed, however, that small differences in physical extraction scenarios only had limited influence on the monetary value of oil and gas reserves. On the other hand, the monetary value choosing a different discount rate and using alternative valuation methods had a larger impact on monetary valuation.

Based on the results it can be concluded that the lifelength of the remaining gas reserves in the Netherlands is around 20 years at the current rate of extraction of around 70 billion Sm^3 each year, assuming no new discoveries. The lifelength of oil reserves in 2005 has been estimated at around 24 years. The results also showed that the monetary value of natural gas reserves in the Netherlands has increased with nearly 60 percent (or 37 billion euro) due to price changes in the period between 1990 and 2005, whereas the physical reserves have decreased with nearly 43 percent (or 1169 billion Sm^3). This finding demonstrates the importance of presenting physical and monetary balance sheets at the same time.

Several issues need to be considered while interpreting the results. First, due to data restrictions on the costs for producing oil and gas, the resource rent was divided between oil and gas based on relative production values. This is probably an inaccurate assumption, because experts indicate that the cost per unit of extracted oil are larger than the cost per unit of extracted natural gas. As a result, the resource rent for oil and the monetary value of oil reserves are likely to be inflated. Since the value of oil reserves is only a small part of total reserves, the potential error is considered to be small. Alternative methods to divide the resource rent between oil and gas may be: (1) using production volume measured in Sm^3 as weights, (2) using the number of wells or drillings for oil and natural gas, or (3) using an estimate of the difference between production cost (e.g., cost for the production of one unit of natural gas are 50 percent of the production cost of one unit of oil). In future research, we will try to get better estimates on cost differences between the extraction of oil and natural gas.

Second, although the physical extraction scenarios that were used are realistic, they have not yet been fully confronted with the physical extraction plans of mining companies. The Dutch organisation in charge of the physical assessment of mineral reserves in the Netherlands (TNO, the Netherlands Organisation of Applied Scientific Research) can provide these numbers for recent years. Obtaining data on physical extraction plans of earlier years may be more complicated. Further research should indicate to what extent our physical extraction scenarios can be improved based on TNO data.

Third, for including the oil and gas reserves in the inputs for productivity measurement, the user cost of the reserves must be determined. The resource rent for oil and gas has been derived endogenously by subtracting the user cost of produced capital from the gross operating surplus. It seems logical that the user cost of the reserves will be equal to the resource rent. However, calculating the user cost of the reserves may lead to different results because of (1) revaluations due to price changes, (2) time differences between valuation of the user cost (end-of-year) and the income from the reserves (year average), and (3) differences between the interest rate for the user cost of the reserves and the user cost of produced capital. Solving these issues is important when inputs from oil and gas reserves are used in productivity analyses.

Fourth, the physical and monetary balance sheets in this report were restricted to oil and natural gas. Other subsoil assets such as coal, sand, salt and gravel have not been considered here. In future research we will determine the monetary values of all subsoil assets that are economically recoverable to complete the monetary balance sheets of subsoil assets in the Netherlands. Currently that does not include coal reserves, but price increases of coal and advances in mining technology may also warrant future research on their valuation.

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Appendix 1: Physical balance sheets for oil and gas reserves in the Netherlands

Resource stock of natural gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Billion standard m^3																
Opening stock																
Remainder of proven reserve 1st January	1 725	1 970	1 950	1 930	1 875	1 845	1 815	1 765	1 787	1 771	1 714	1 655	1 616	1 567	1 482	1 445
Remainder of expected reserve 1st-January	1 865	2 113	2 086	2 061	2 010	1 997	1 952	1 930	1 947	1 893	1 836	1 777	1 738	1 689	1 615	1 572
Opening stock:	1 865	2 113	2 086	2 061	2 010	1 997	1 952	1 930	1 947	1 893	1 836	1 777	1 738	1 689	1 615	1 572
Reappraisal (gross) (+)	248	- 27	- 25	- 51	- 13	- 45	- 22	13	- 60	- 59	- 60	- 38	- 48	- 75	- 43	- 104
Reappraisal (net) (+):	248	- 27	- 25	- 51	- 13	- 45	- 22	17	- 54	- 57	- 59	- 39	- 47	- 75	- 43	- 104
New discoveries (+)	33	22	47	19	46	15	40	41	32	22	25	39	23	13	10	15
Re-evaluation of discovered resources (+)	287	33	11	14	19	18	28	54	- 12	- 9	- 17	- 5	0	- 19	25	- 46
Gross Extraction (at the expense of the reserve) (-)	72	82	83	84	78	78	90	82	80	72	68	72	71	69	78	73
Net Extraction (Gross including underground storage)	72	82	83	84	78	78	90	78	74	70	67	73	71	69	78	73
Other adjustments (= remainder)	0	0	0	0	0	0	0	0	0	0	0	0	- 2	1	0	42
Net closing stock (balanced via 'other adjustments')	2 113	2 086	2 061	2 010	1 997	1 952	1 930	1 947	1 893	1 836	1 777	1 738	1 689	1 615	1 572	1 510
Production from underground storage facility [1]								- 4	- 6	- 2	- 1	1	- 1	0	0	0
Underground storage of natural gas: (-/- = net injection)								3.8	6.1	2.1	0.7	- 0.6	0.5	- 0.4	- 0.4	0.1
Injection								3.8	6.6	2.2	0.8	0.8	1.3	0.0	1.9	1.4
Production								0.0	0.6	0.2	0.1	1.4	0.8	0.4	2.3	1.3

[1] In 1997 natural has been injected in one of the underground storage facilities for the first time.

Resource stock of oil	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Million standard m^3																
Opening stock																
Remainder of proven reserve 1st January	25.0	23.0	23.0	21.0	18.0	17.0	14.0	18.0	20.0	17.0	15.0	13.0	11.0	9.0	.	.
Remainder of expected reserve 1st January	68.0	64.0	64.0	61.0	58.0	56.0	50.0	55.0	37.0	34.0	32.0	30.0	28.0	26.0	38.0	34.0
Opening stock:	68.0	64.0	64.0	61.0	58.0	56.0	50.0	55.0	37.0	34.0	32.0	30.0	28.0	26.0	38.0	34.0
Reappraisal (gross) (+)	- 4.0	- 3.7	- 3.2	- 3.0	- 4.0	- 3.2	- 2.6	- 2.5	- 2.0	- 1.9	- 1.7	- 1.6	- 2.7	16.9	- 4.2	- 7.1
New discoveries (+)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Re-evaluation of discovered resources (+)	.	.	.	.	.	.	.	.	.	.	.	.	.	19.6	- 1.7	- 5.3
Production / Extraction (-)	4.0	3.7	3.2	3.0	4.0	3.2	2.6	2.5	2.0	1.9	1.7	1.6	2.7	2.7	2.5	1.8
Other adjustments (= remainder)	0.0	3.7	0.2	0.0	2.0	- 2.8	7.6	- 15.5	- 1.0	- 0.1	- 0.3	- 0.4	0.7	- 4.9	0.2	9.0
Net closing stock (balanced via 'other adjustments')	64.0	64.0	61.0	58.0	56.0	50.0	55.0	37.0	34.0	32.0	30.0	28.0	26.0	38.0	34.0	35.9

[1] For 2004 and 2005 the 'proven reserves' were not reported.

Appendix 2: Monetary balance sheets for oil and gas reserves in the Netherlands

Monetary valuation of gas reserves	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	mln euro															
Opening stocks 1-1	62 493	69 236	74 569	75 186	69 035	60 950	60 742	64 304	71 773	70 799	63 624	64 444	78 894	91 418	92 747	89 317
Revaluation	3 110	6 980	841	-5 472	-7 475	1 192	4 802	8 386	229	-6 478	6 362	18 640	13 782	3 340	-2 806	14 005
Stock after revaluation	65 603	76 216	75 410	69 714	61 560	62 143	65 544	72 689	72 002	64 321	69 986	83 084	92 676	94 758	89 941	103 322
Revaluation due to time passing	2 624	3 049	3 016	2 789	2 462	2 486	2 622	2 908	2 880	2 573	2 799	3 323	3 707	3 790	3 598	4 133
Stock after revaluation due to time passing	68 227	79 265	78 426	72 503	64 023	64 628	68 166	75 597	74 882	66 894	72 786	86 407	96 383	98 548	93 539	107 454
Extraction	-4 483	-5 841	-4 435	-4 191	-4 075	-4 375	-5 501	-5 635	-4 259	-3 248	-5 708	-7 779	-6 294	-6 618	-7 579	-9 383
Stock after extraction	63 744	73 424	73 991	68 312	59 948	60 253	62 665	69 962	70 622	63 646	67 078	78 629	90 089	91 930	85 960	98 072
Other changes	5 491	1 144	1 195	723	1 002	489	1 639	1 811	176	- 21	-2 634	265	1 329	817	3 357	1 775
Closing stocks 31-12	69 236	74 569	75 186	69 035	60 950	60 742	64 304	71 773	70 799	63 624	64 444	78 894	91 418	92 747	89 317	99 846

Monetary valuation of oil reserves	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	mln euro															
Opening stocks 1-1	3 334	3 525	3 865	3 473	2 679	2 081	1 692	2 049	1 765	1 520	1 302	1 690	2 119	2 419	2 917	2 726
Revaluation	482	410	- 253	- 680	- 620	- 238	307	414	- 126	- 116	665	619	284	- 303	- 50	639
Stock after revaluation	3 816	3 936	3 612	2 793	2 059	1 842	1 999	2 464	1 640	1 404	1 968	2 309	2 404	2 117	2 867	3 365
Revaluation due to time passing	153	157	144	112	82	74	80	99	66	56	79	92	96	85	115	135
Stock after revaluation due to time passing	3 968	4 093	3 756	2 905	2 142	1 916	2 079	2 562	1 705	1 461	2 046	2 401	2 500	2 201	2 982	3 500
Extraction	- 386	- 324	- 240	- 154	- 170	- 174	- 194	- 185	- 92	- 111	- 254	- 216	- 293	- 283	- 305	- 321
Stock after extraction	3 582	3 769	3 516	2 751	1 972	1 742	1 885	2 378	1 613	1 350	1 792	2 185	2 207	1 919	2 677	3 178
Other changes	- 57	96	- 43	- 72	108	- 49	164	- 612	- 93	- 47	- 102	- 66	213	999	49	95
Closing stocks 31-12	3 525	3 865	3 473	2 679	2 081	1 692	2 049	1 765	1 520	1 302	1 690	2 119	2 419	2 917	2 726	3 273