TALL SOM FORTELLER

Incorporating depletion as production cost into the national accounts

PRESENTED AT TALLINN FOR THE 31ST LONDON GROUP MEETING

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Agenda

1. Background
2. Present and suggested treatment of depletion
3. Measuring depletion
4. Including depletion in the sequence of economic accounts
5. Impact on some headline indicators
6. Concluding remarks

Background

- System of National Accounts (SNA) update (from 2008 SNA to 2025 SNA): *Natural Capital* more visible!
- But including oil and gas as asset (AN.212) into national accounts is in fact **NOT NEW** (already in 2008 SNA and ESA 2010 (European System of Accounts))! The net present value (NPV) method is generally recommended.
- System of Environmental-Economic Accounting 2012 - Central Framework (SEEA-CF): concrete suggestions on implementation of the NPV method; recording depletion as production cost.
- Measurement of Norwegian petroleum resources as asset has been carried out by a project partially financed by Eurostat (Project number and acronym: 101122519, 2022-NO-SNA-UPDATE):
  1. Liu, G. and S. Midttun (2024a), 'Compiling physical asset accounts for petroleum resources in Norway', *Documents*, 2024/7, Statistics Norway.
  2. Liu, G. and S. Midttun (2024b), 'Is it necessary and feasible to estimate the asset value from oilfield level?', *Documents*, 2024/8, Statistics Norway.
  3. Liu, G. and S. Midttun (2024c), 'Including petroleum resources as asset in the Norwegian national accounts', paper presented at the 38th IARIW General Conference in London, August 2024.
- The split-asset approach: Liu, G. (2023), 'Testing the split of economic ownership for petroleum resources in Norway', *Documents*, 2023/24, Statistics Norway.

Present and suggested treatment of depletion

- The concept of depletion: '*A reduction in something*' (according to an online Cambridge Dictionary)
- Depletion in the 2008 SNA: NOT as production cost, but as 'other changes' in the 'other changes in the volume of assets account', therefore not recorded in the current accounts of the SNA, including the production, and the generation, allocation, redistribution, and use of income accounts.
- Depletion in the SEEA-CF: treated with more detail and precision than in SNA.
- Suggestions by the SNA update Task Team (now adopted in the new 2025 SNA):
  - Depletion as a production cost
  - A new entry called 'depletion borne by government'
  - Split-asset approach

Measuring depletion – in physical and value terms

(1) $$V^{tB} = \sum_{\tau=1}^{T^{tB}} [NR^{t+\tau-1}/(1+\delta_t)^{\tau}] = \sum_{\tau=1}^{T^{tB}} [UR_N^{t+\tau-1} X^{t+\tau-1}/(1+\delta_t)^{\tau}]$$

(2) $$P^{tB} = V^{tB}/S^{tB}$$

(3) $$S^{t+1B} = S^{tB} + I_t - L_t - X_t$$

(4) $$D_t = X_t - G_t$$

(5) $$V^{t+1B} - V^{tB} = P^{t+1B} S^{t+1B} - P^{tB} S^{tB}$$

(8) $$V^{t+1B} - V^{tB} = [(P^{tB} + P^{t+1B})/2](S^{t+1B} - S^{tB}) + (P^{t+1B} - P^{tB})[(S^{tB} + S^{t+1B})/2] = [(P^{tB} + P^{t+1B})/2](I_t - L_t - X_t) + (P^{t+1B} - P^{tB})[(S^{tB} + S^{t+1B})/2]$$

Measuring depletion – in physical and value terms (cont.)

(9) Opening stock (at the beginning of year t): $V^{tB} = P^{tB}S^{tB}$

\+ Additions (e.g., discoveries): $[(P^{tB} + P^{t+1B})/2]I_t$

\- Depletion: $[(P^{tB} + P^{t+1B})/2]X_t$

\- Other reductions (e.g., catastrophic losses): $[(P^{tB} + P^{t+1B})/2]L_t$

\+ Revaluation due to price changes: $(P^{t+1B} - P^{tB})[(S^{tB} + S^{t+1B})/2]$

= Closing stock (the asset value at the end of year t): $V^{t+1B} = P^{t+1B}S^{t+1B}$

Measuring depletion – in *ex-ante* and *ex-post* terms

(10) $S^{tB} - S^{tB}_{t+1} = X^t$ (*ex-ante* depletion, see para. A5.21 in SEEA-CF)

(11) $S^{t+1B} - S^{tB}_{t+1} = I_t - L_t$ (see para. A5.23 in SEEA-CF)

(12) $S^{t+1B} = S^{tB} + I_t - L_t - X^t$ (Note the difference from equation (3))

(3) $S^{t+1B} = S^{tB} + I_t - L_t - X_t$ (Defining a correction to the *ex-ante* depletion as:)

(13) $\Delta X(t) = X_t - X^t$ (Then equation (11) should be:)

(14) $S^{t+1B} - S^{tB}_{t+1} = I_t - L_t - \Delta X(t)$

(15) $S^{t+1B} = S^{tB} + I_t - L_t - X_t$ (Equation (15) is the same as equation (3))

Measuring depletion – asset account for petroleum resources

	Opening stock		- Depletion		+ Other changes		+ Revaluation	= Closing stock	
Year	Quantity	Value	Quantity	Value	Quantity	Value	Value	Quantity	Value
1970	9041	303741	0	0	0	0	35361	9041	339102
1971	9041	339102	0	14	0	0	39224	9040	378311
1972	9040	378311	2	86	0	0	46609	9038	424835
1973	9038	424835	2	95	0	0	64454	9036	489194
1974	9036	489194	2	118	0	0	79095	9034	568171
1975	9034	568171	11	739	0	0	77578	9023	645010
1976	9023	645010	16	1236	0	0	84254	9007	728029
1977	9007	728029	19	1663	0	0	90958	8988	817324
1978	8988	817324	35	3343	0	0	68722	8952	882703
1979	8952	882703	45	4695	0	0	112404	8908	990412
1980	8908	990412	56	6699	0	0	136808	8851	1120521
1981	8851	1120521	55	7399	0	0	140728	8796	1253850
1982	8796	1253850	55	8215	0	0	123366	8741	1369001
1983	8741	1369001	62	10000	0	0	102461	8680	1461462
1984	8680	1461462	69	12078	0	0	97156	8611	1546540
1985	8611	1546540	73	13708	0	0	126146	8537	1658977
1986	8537	1658977	79	16306	0	0	212902	8458	1855573
1987	8458	1855573	90	20657	0	0	190903	8369	2025819
1988	8369	2025819	98	24972	0	0	203452	8271	2204299
1989	8271	2204299	120	33387	0	0	191841	8151	2362753
1990	8151	2362753	126	37825	0	0	182660	8025	2507587
1991	8025	2507587	139	44882	0	0	164653	7886	2627359
1992	7886	2627359	156	50765	925	301800	-111229	8655	2767164
1993	8655	2767164	163	53180	236	76939	100092	8728	2891016
1994	8728	2891016	184	61339	567	189241	48378	9111	3067296
1995	9111	3067296	197	67935	222	76558	15039	9136	3226309
1996	9136	3226309	226	76705	1482	502507	-275899	10392	3376211
1997	10392	3376211	234	77530	352	116672	142844	10510	3558199
1998	10510	3558199	228	79026	404	139964	162894	10686	3782031
1999	10686	3782031	230	84593	57	20934	297792	10513	4016163
2000	10513	4016163	241	91870	521	198498	-25801	10793	4096990
2001	10793	4096990	252	97242	33	12798	146730	10574	4159276
2002	10574	4159276	258	105247	-90	-36562	293869	10226	4311336
2003	10226	4311336	262	118236	-826	-373150	585764	9139	4405715
2004	9139	4405715	264	129953	-35	-17089	176390	8840	4435062
2005	8840	4435062	258	129618	183	91912	26947	8765	4424303
2006	8765	4424303	249	125772	52	26285	1052	8568	4325868
2007	8568	4325868	238	121543	87	44284	114919	8417	4363527
2008	8417	4363527	243	124093	202	103154	-129407	8376	4213181
2009	8376	4213181	240	123385	-71	-36488	181741	8065	4235049
2010	8065	4235049	231	127105	-521	-286967	399599	7314	4220576
2011	7314	4220576	219	123429	289	163032	-184854	7384	4075324
2012	7384	4075324	225	120235	444	237447	-250174	7603	3942362
2013	7603	3942362	214	106827	586	292800	-290519	7975	3837817
2014	7975	3837817	216	105202	-23	-11158	78470	7736	3799926
2015	7736	3799926	228	114360	89	44721	164062	7597	3894349
2016	7597	3894349	231	122377	55	29195	269131	7421	4070298
2017	7421	4070298	237	122798	1325	687418	-474634	8510	4160284
2018	8510	4160284	227	112067	21	10386	68673	8303	4127276
2019	8303	4127276	214	108298	99	50087	154443	8188	4223509
2020	8188	4223509	227	122163	29	15551	361265	7990	4478162
2021	7990	4478162	231	134625	89	51849	357529	7848	4752915

Table 3.1 Asset account for Norwegian petroleum resources in both quantity (Sm³ o. e. million) and value (current prices, NOK million), 1970-2021

Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.

Note: The asset value of petroleum resources is estimated by using an estimated annual nominal rate of return to produced capital and an annual real discount rate of 4% (see Liu and Midttun, 2025).

Measuring depletion – depletion and net income

(16) $$V^{tB} = \sum_{\tau=1}^{T^{tB}} [NR^{t+\tau-1}/(1+\delta_t)^{\tau}] = NR^t/(1+\delta_t) + \left\{\sum_{\tau=2}^{T^{tB}} [NR^{t+\tau-1}/(1+\delta_t)^{\tau}]\right\}$$

$$= NR^t/(1+\delta_t) + \left\{\sum_{\tau^*=1}^{T^{tB}} \left[NR^{t+\tau^*}/(1+\delta_t)^{\tau^*}\right]\right\}/(1+\delta_t)$$

$$= NR^t/(1+\delta_t) + V_{t+1}^{tB}/(1+\delta_t)$$

(17) $$V_{t+1}^{tB} - V^{tB} = -[(P^{tB} + P_{t+1}^{tB})/2]X^t + (P_{t+1}^{tB} - P^{tB})[(S^{tB} + S_{t+1}^{tB})/2]$$

(19) $$NR^t - [(P^{tB} + P_{t+1}^{tB})/2]X^t = \delta_t V^{tB} - (P_{t+1}^{tB} - P^{tB})[(S^{tB} + S_{t+1}^{tB})/2]$$

(20) Depletion-adjusted resource rent = $NR_t - [(P^{tB} + P^{t+1B})/2]X_t$ (Definition!)

Measuring depletion – depletion and net income (cont.)

	Estimated nr, r=4%		rr=4%, r=4%		rr=7%, r=7%	
Year	Resource rent	Net income	Resource rent	Net income	Resource rent	Net income
1970	-141	-141	-133	-133	-160	-160
1971	-236	-251	-228	-242	-275	-280
1972	-286	-372	-273	-356	-355	-385
1973	-481	-576	-446	-538	-562	-596
1974	-809	-927	-742	-856	-970	-1013
1975	1309	570	1331	615	960	677
1976	2281	1045	2181	983	1600	1115
1977	1767	104	1512	-101	566	-104
1978	6939	3595	6412	3168	5323	3941
1979	13525	8830	12936	8380	11609	9634
1980	31347	24647	30352	23850	28599	25774
1981	36763	29365	35561	28380	33252	30153
1982	38754	30539	37362	29387	34382	30963
1983	47620	37620	46006	36296	42517	38385
1984	59543	47464	58143	46416	53951	49034
1985	60848	47140	59088	45779	53975	48495
1986	18278	1972	14989	-855	9045	2491
1987	13221	-7435	8156	-11958	1161	-7396
1988	-509	-25481	-6353	-30734	-14072	-24828
1989	20593	-12794	15575	-17102	7250	-7665
1990	34473	-3352	30631	-6451	21900	4547
1991	32049	-12832	29935	-14107	20636	-446
1992	24856	-25909	24294	-25536	14191	-10255
1993	21115	-32064	22928	-29252	11895	-14434
1994	20000	-41339	22349	-37787	10776	-20446
1995	23836	-44099	26868	-39665	14763	-20794
1996	64707	-11998	65634	-9421	52832	11786
1997	70062	-7468	71447	-4352	57648	15357
1998	10741	-68285	11914	-65300	-3264	-47508
1999	52961	-31632	51194	-31449	34988	-13810
2000	214537	122667	212796	123074	195971	142298
2001	191128	93886	190885	96008	173145	116211
2002	147995	42749	147564	44974	129872	67727
2003	151720	33484	155608	40513	137237	66578
2004	212424	82471	219346	93148	200456	122279
2005	300278	170660	309220	183805	288745	211093
2006	372666	246894	381789	260684	359546	285469
2007	327270	205727	333720	217290	308840	238725
2008	451569	327476	452773	334504	424604	355015
2009	245918	122533	235989	118755	204601	136813
2010	274729	147624	272655	152108	239405	169874
2011	390062	266633	377957	261192	341591	275244
2012	407082	286847	395403	281954	355888	293327
2013	359494	252667	348186	247674	304546	250882
2014	284084	178882	271745	172969	223777	172197
2015	159957	45597	142479	35062	92077	35777
2016	71337	-51040	53576	-61707	3338	-58996
2017	190074	67276	169996	53982	121330	56846
2018	311835	199768	286984	180857	237221	177848
2019	183896	75598	153936	50998	101949	43831
2020	48937	-73226	6144	-110863	-48756	-117316
2021	648952	514328	611463	481986	555677	477872

Table 3.2 Annual resource rent and depletion-adjusted resource rent (net income) generated by Norwegian petroleum resources over 1970-2021 (current prices, NOK million)
Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.
Note: 'Estimated nr' stands for 'estimated annual nominal rate of return' and 'rr' for 'annual real rate of return' to produced capital in petroleum extraction industry; 'r' stands for 'annual real discount rate'.

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Including depletion in the sequence of economic accounts – production account

		Uses			Resources		
Code	Transactions and balancing items	S11	S13	S1	S11	S13	S1
P1	Output				5138768	1046289	6983852
P2	Intermediate consumption	2446204	311009	3089372			
D21-D31	Net (of subsidies) taxes on products						429451
B1g	Value added, gross/GDP	2692564	735280	4323931			
P51c	Consumption of fixed capital	443197	149366	747569			
B1n	*Value added, net/NDP*	2249367	585914	3576362			
	Depletion	*134625*		*134625*			
	Depletion-adjusted net value added/NDP	*2114742*	585914	*3441737*			

Table 4.1 Production account for 2021 (current prices, NOK million)
Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.
Note: The asset value and depletion of petroleum resources are estimated by using an estimated annual nominal rate of return to produced capital and an annual real discount rate of 4% (see Liu and Midttun, 2025).

Including depletion in the sequence of economic accounts – generation of income account

		Uses			Resources		
Code	Transactions and balancing items	S11	S13	S1	S11	S13	S1
B1g	Value added, gross				2692564	735280	3894480
B1n	*Value added, net*				2249367	585914	3146911
	Depletion-adjusted net value added				*2114742*	585914	*3012286*
D1	Compensation of employees	1131728	585748	1844012			
D29-D39	Net (of subsidies) other taxes on production	-28416	166	-39863			
	Change due to specific taxes	*-6138*		*-6138*			
	Updated D29-D39	*-34554*	166	*-46001*			
B2g	Operating surplus, gross	1589252	149366	2090331			
	Updated B2g	*1595390*	149366	*2096469*			
B2n	*Operating surplus, net*	1146055	0	1342762			
	Updated B2n	*1152193*	0	*1348900*			
	Depletion-adjusted net operating surplus	*1017568*	0	*1214275*			

Table 4.2 Generation of income account for 2021 (current prices, NOK million)
Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.
Note: The asset value and depletion of petroleum resources are estimated by using an estimated annual nominal rate of return to produced capital and an annual real discount rate of 4% (see Liu and Midttun, 2025).

Including depletion in the sequence of economic accounts – allocation of primary income account

		Uses			Resources		
Code	Transactions and balancing items	S11	S13	S1	S11	S13	S1
B2g	Operating surplus, gross				1589252	149366	2090331
	Updated B2g				*1595390*	149366	*2096469*
B2n	*Operating surplus, net*				1146055	0	1342762
	Updated B2n				*1152193*	0	*1348900*
	Depletion-adjusted net operating surplus				*1017568*	0	*1214275*
D1	Compensation of employees						1815469
D2-D3	Net (of subsidies) taxes on production and imports					389588	389588
	Change due to specific taxes					*-6138*	*-6138*
	Updated D2-D3					383450	383450
D4	Property income	1012460	18816	1409878	528382	514181	1513150
	Change due to specific taxes	*+6138*		*+6138*		*+6138*	*+6138*
	Change due to special income taxes	*+33728*		*+33728*		*+33728*	*+33728*
	Updated D4	*1052326*	18816	*1449744*	528382	*554047*	*1553016*
	Depletion borne by government		*+94238*	*+94238*	*+94238*		*+94238*
	Adjusted by split-depletion	*1052326*	*113054*	*1543982*	*622620*	*554047*	*1647254*
B5g	Balance of primary income, gross / National income, gross	1105174	1034319	4398660			
	Updated B5g	*1071446*	*1068047*	*4398660*			
B5n	*Balance of primary income, net / National income, net*	661977	884953	3651091			
	Updated B5n	*628249*	*918681*	*3651091*			
	Depletion-adjusted net balance of primary income	*587862*	*824443*	*3516466*			

Table 4.3 Allocation of primary income account for 2021 (current prices, NOK million)
Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.
Note: The asset value and depletion of petroleum resources are estimated by using an estimated annual nominal rate of return to produced capital and an annual real discount rate of 4% (see Liu and Midttun, 2025).

Including depletion in the sequence of economic accounts – secondary distribution of income account

		Uses			Resources		
Code	Transactions and balancing items	S11	S13	S1	S11	S13	S1
B5g	Balance of primary income, gross / National income, gross				1105174	1034319	4398660
	Updated B5g				*1071446*	*1068047*	*4398660*
B5n	*Balance of primary income, net / National income, net*				661977	884953	3651091
	Updated B5n				*628249*	*918681*	*3651091*
	Depletion-adjusted net balance of primary income				*587862*	*824443*	*3516466*
	Current transfers	389096	-612881	67817			
	Change due to special income taxes	*-33728*	*+33728*				
	Updated current transfers	*355368*	*-579153*	67817			
B6g	Disposable income, gross	716078	1647200	4330843			
	Updated B6g	*716078*	*1647200*	*4330843*			
B6n	*Disposable income, net*	272881	1497834	3583274			
	Updated B6n	*272881*	*1497834*	*3583274*			
	Depletion-adjusted net disposable income	*232494*	*1403596*	*3448649*			

Table 4.4 Secondary distribution of income account for 2021 (current prices, NOK million)
Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate. Note: The asset value and depletion of petroleum resources are estimated by using an estimated annual nominal rate of return to produced capital and an annual real discount rate of 4% (see Liu and Midttun, 2025).

Including depletion in the sequence of economic accounts – use of disposable income account

		Uses			Resources		
Code	Transactions and balancing items	S11	S13	S1	S11	S13	S1
B6g	Disposable income, gross				716078	1647200	4330843
B6n	*Disposable income, net*				272881	1497834	3583274
	Depletion-adjusted net disposable income				*232494*	*1403596*	*3448649*
P3	Final consumption expenditure	0	970694	2597042			
D8	Adjustment for the change in pension entitlements			5376			
B8g	Saving, gross	716078	676506	1728425			
B8n	*Saving, net*	272881	527140	980856			
	Depletion-adjusted net saving	*232494*	*432902*	*846231*			

Table 4.5 Use of disposable income account for 2021 (current prices, NOK million)
Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.
Note: The asset value and depletion of petroleum resources are estimated by using an estimated annual nominal rate of return to produced capital and an annual real discount rate of 4% (see Liu and Midttun, 2025).

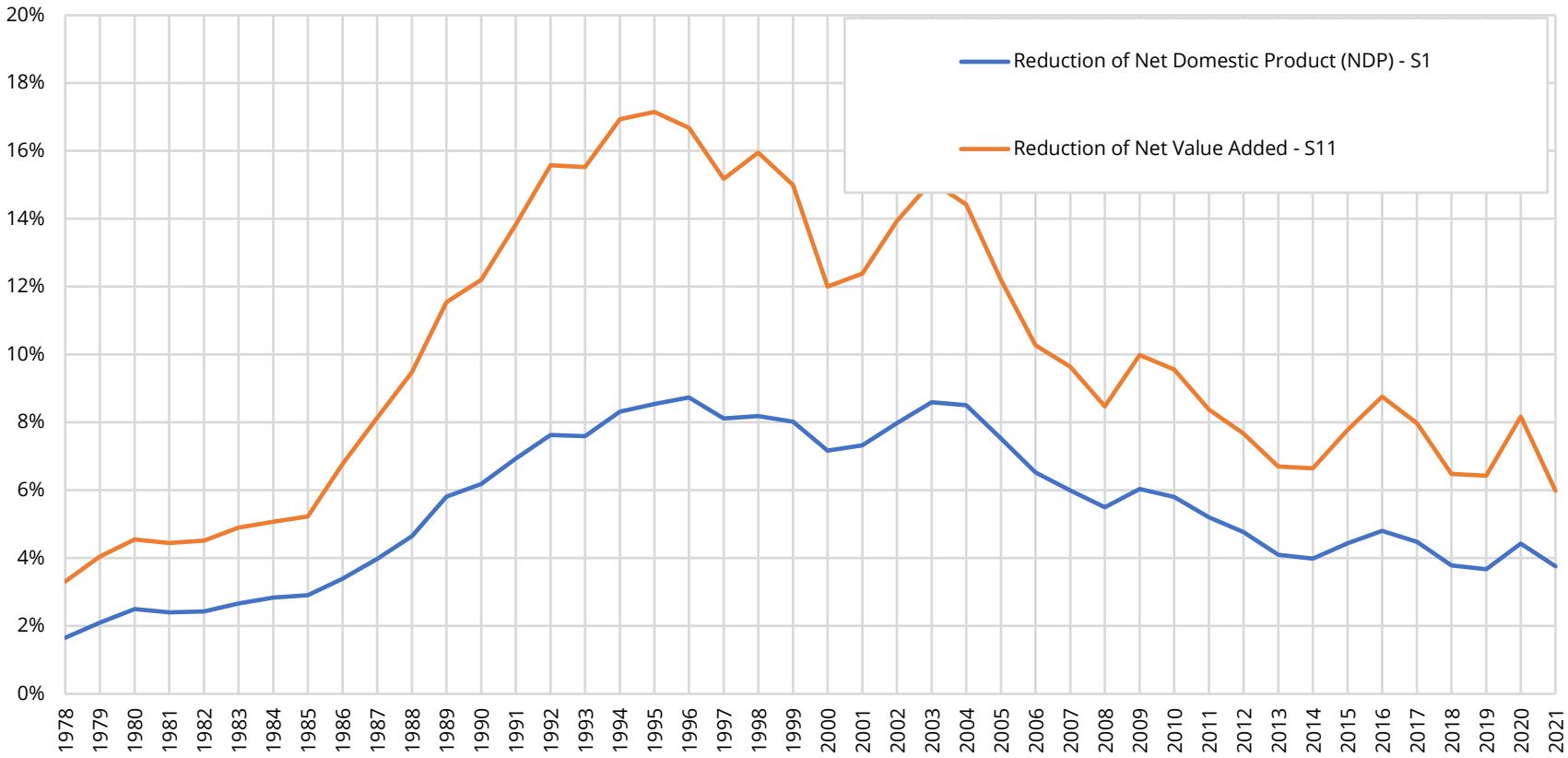
Including depletion in the sequence of economic accounts – capital account

		Changes in assets			Changes in liabilities and net worth		
Code	Transactions and balancing items	S11	S13	S1	S11	S13	S1
B8n	*Saving, net*				272881	527140	980856
	Depletion-adjusted net saving				*232494*	*432902*	*846231*
P5g	Gross capital formation	615881	220457	1084790			
P51c	Consumption of fixed capital	-443197	-149366	-747569			
NP	Acquisitions less disposals of non-produced assets	-2761	-476	-164			
	Depletion	*-40387*	*-94238*	*-134625*			
D9	Capital transfers, net				10925	-11768	-1191
B9	*Net lending (+)/borrowing (-)*	113883	444757	642608			
	Depletion-adjusted net lending (+)/borrowing (-)	*113883*	*444757*	*642608*			

Table 5.1 The capital account for 2021 (current prices, NOK million)
Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.
Note: The asset value and depletion of petroleum resources are estimated by using an estimated annual nominal rate of return to produced capital and an annual real discount rate of 4% (see Liu and Midttun, 2025).

Impact on some headline indicators over 1978-2021 - NDP

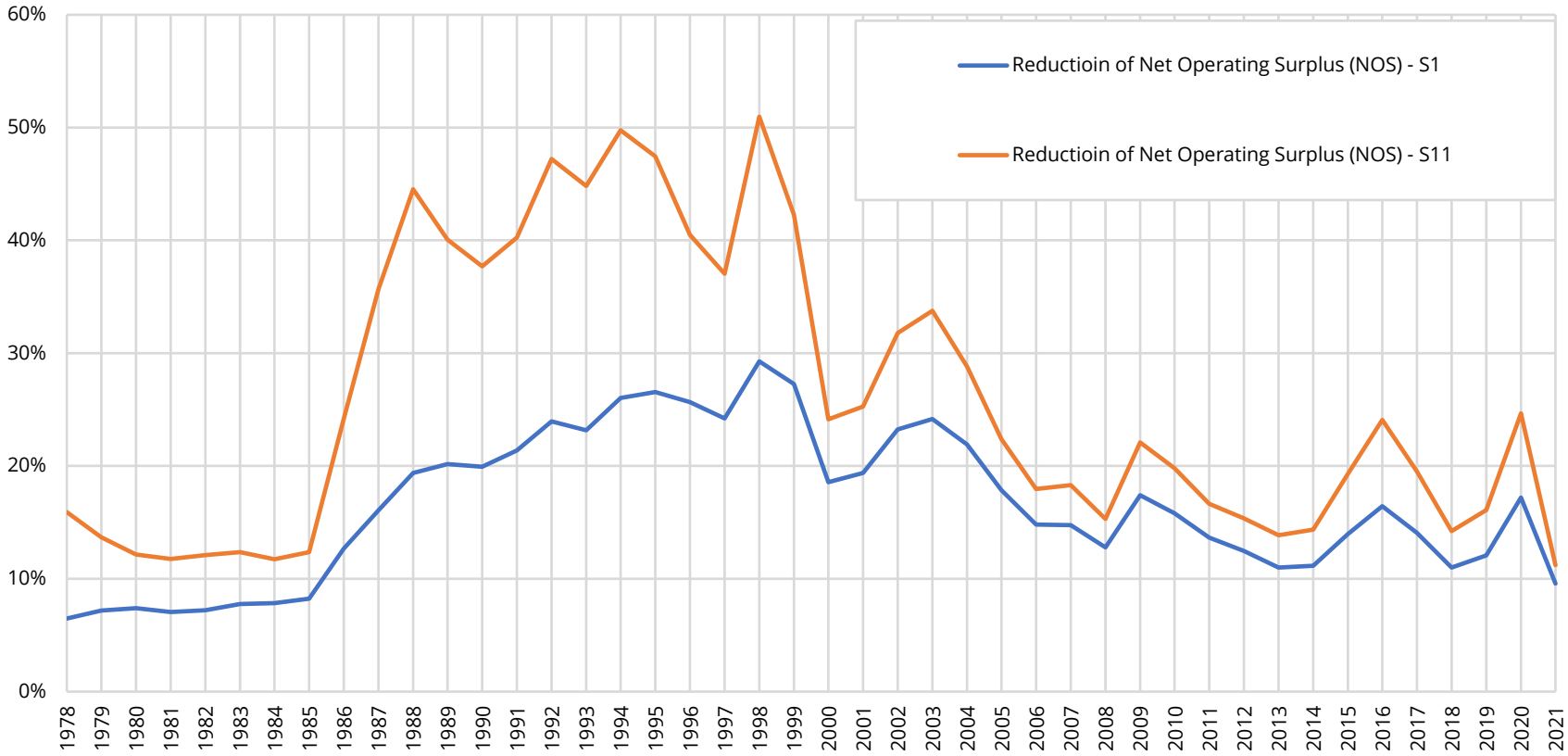
Figure 6.1 Impact on net value added and net domestic product (NDP) (%), 1978-2021



Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.
Note: The asset value and depletion of petroleum resources are estimated by using an estimated annual nominal rate of return to produced capital and an annual real discount rate of 4% (see Liu and Midttun, 2025).

Impact on some headline indicators over 1978-2021 - NOS

Figure 6.2 Impact on net operating surplus (%), 1978-2021



Source: Authors' own calculation based on data from Statistics Norway and the Norwegian Offshore Directorate.
Note: The asset value and depletion of petroleum resources are estimated by using an estimated annual nominal rate of return to produced capital and an annual real discount rate of 4% (see Liu and Midttun, 2025).

Concluding remarks

- Depletion is regarded as the running down of natural resources beyond its regeneration level.
- In this paper, a coherent and consistent accounting framework is presented in which the change of the asset between the opening and the closing accounting period, either in physical or in value terms, is decomposed into various components, including depletion, other changes, and revaluation.
- The accounting framework as reported in this paper is also in line with the general capital measurement framework as described in *Measuring Capital OECD Manuel* (Schreyer, 2009) and in Liu (2024). In addition, the formulation as set up in this paper has removed some imprecisions as presented in the current SEEA-CF.
- With the backup of the capital measurement theory, this paper defines an *ex-post* depletion-adjusted resource rent or the net income. By using the estimated resource rent and asset value (see Liu and Midttun, 2025) and other Norwegian data, the annual asset account of Norwegian petroleum resources and the calculated depletion-adjusted resource rent or the net income over the period 1970-2021 are reported.
- Using the Norwegian 2021 data, this paper illustrates how to incorporate depletion as production cost into the sequence of the institutional sector accounts by following the suggested split-asset approach. Finally, by using the time series data over the period 1978-2021 drawn from the Norwegian institutional sector accounts, the paper also demonstrates the impact on some headline indictors due to the inclusion of depletion as a cost of production.

TALL
SOM FORTELLER

Takk!

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