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Oil, National Wealth, and Current and Future Consumption Possibilities

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Abstract

This paper offers a discussion about the macroeconomics of exhaustible resources. In a resource-based economy, long-term sustainability is an obvious issue. This paper outlines some ideas on how to treat issues related to exhaustible resources in a macroeconomic context. Based on a small dynamic general equilibrium model, the approach is demonstrated with the help of some simple numerical examples.

JEL CLASSIFICATION NUMBERS:

E20; Q30

* I have benefited from discussions with Arent Skjæveland and Lars E.O. Svensson. However, remaining errors are my own. The views expressed in this paper are those of the author and do not necessarily reflect the views of the International Monetary Fund.

Table of Contents

Summary

Taking Norway as a point of departure, this paper offers a discussion about the macroeconomics of exhaustible resources. The exploitation of exhaustible resources differs from other economic activities in that the revenues generated partly represent a depletion of wealth, or equivalently, economic rent. In an economy based on natural resources, traditional national accounting concepts are typically misleading. To provide a more meaningful picture, the rent income from exhaustible resources should be deducted from the traditional income concept. Similarly, in order to get a fair idea of how much the economy can afford to spend, the permanent income from natural resources should be included.

The reserves of oil and gas represent an important part of Norway's national wealth. Together with other components of national wealth, Norway's oil wealth is a major determinant of current and future consumption possibilities. Taking into account the permanent income from oil wealth, the non-oil current account deficit can register significant deficits without an erosion of national wealth. With the bulk of Norway's oil wealth owned by the public sector, the same argument can be made about the non-oil government budget balance.

In an economy based on exhaustible resources, the sustainability of consumption or, more correctly, the national saving rate, is an obvious issue. As regards sustainability, simple indicators can go a long way, but determining whether or not a particular situation is sustainable is usually not enough. This paper outlines some ideas on how to treat problems related to exhaustible resources in a macroeconomic context. The paper argues that instead of focusing on the overall current account, or for that matter, the non-oil current account, one should focus on national wealth. As the economy's intertemporal budget constraint, national wealth ultimately determines the room for public and private consumption. National wealth measures future consumption possibilities and is therefore a natural policy target. On the basis of a dynamic general equilibrium model, the basic approach is demonstrated with the help of some simple exercises.

I. Introduction

Oil has played a prominent role in the Norwegian economy since the early 1970s when large-scale exploitation of the fields in the North sea first started. At present, oil accounts for a large part of export revenue while taxes and royalties from oil activities make a significant contribution to the government budget (Table 1). To some observers, the build-up of the oil sector has not been entirely without problems. While the non-oil tradable goods sector has been lagging, there have been concerns that too much oil income has been used for current purposes. Indeed, the need for expanding the non-oil tradable goods sector and increasing saving has long been a central theme in the Norwegian debate. 1/

This paper offers a brief discussion of the role of exhaustible resources as a determinant of current and future consumption possibilities. One issue concerns the extent to which the present level of consumption limits consumption growth in the future. Considering the extraordinary uncertainty attached to the value of oil and gas reserves, such an issue is usually not easy to resolve. In the Norwegian case, simple calculations nevertheless suggest that the non-oil current account deficit can be considered sustainable or, in any case, close to sustainable at current oil price projections. The non-oil deficit in government finances is a different matter. In order to fulfill its intertemporal budget constraint, the Norwegian Government may need to reduce its non-oil deficit in the longer run.

A perhaps more important issue is that of desirability. The fact that a certain development may be unsustainable does not necessarily make it undesirable. Large deficits today, it could be argued, may simply be a reflection of a preference for current as compared to future consumption. While this may be true for deficits that originate in the private sector, what about deficits in the government budget? The answer to this question basically depends on the degree of foresight with respect to future tax increases. If future tax increases are not fully discounted, it is important that policymakers consider the consequences of their actions on future consumption possibilities. For this purpose, it is necessary to move beyond simple sustainability indicators. This paper briefly outlines some ideas on how an explicit analytical framework to deal with intertemporal trade-offs of the type facing the Norwegian economy should be constructed.

The remainder of this paper is organized as follows. The next section offers some background on key issues in the economics of exhaustible resources and develops the basic ideas how revenues from oil ought to be treated. These ideas are applied in a formal framework in the following section where it is shown how macroeconomic planning can help in tracing out

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1/ See for example Skånland (1982) and Skånland (1990).

Table 1. Indicators of Oil Dependence

	1986	1987	1988	1989	1990
	(*In percent of non-oil GDP*)				
Oil sector GDP	12.4	11.5	9.5	13.9	16.6
Exports of crude oil and natural gas	11.6	10.6	9.1	13.3	15.4
Government oil revenue	4.0	3.1	1.9	4.2	6.6
	(*In percent of total exports*)				
Exports of crude oil and natural gas	27.3	26.8	22.7	28.1	30.2

Source: Central Bureau of Statistics, *Økonomiske analyser*, various issues.

the intertemporal consequences of different policies. The main tool is a general equilibrium model based on intertemporal optimization by firms and households. This model pays particular attention to the relations between flows and stocks and can be used to examine a range of intertemporal issues. In order to demonstrate the capabilities of the model, some simple numerical examples are presented on the basis of the current Norwegian situation. The last section summarizes and concludes the paper.

II. The Economics of Exhaustible Resources

The exploitation of exhaustible resources differs from other economic activities in that the revenues that are generated partly represent a depletion of wealth. Since the classical article by Hotelling (1931), it has been customary to divide revenues from resource exploitation into two components. The first component consists of compensation to factors of production employed in extracting the resource. This is a normal economic activity which in the absence of market imperfections should yield a normal return. The second component is rent which accrues to the owners of the resource because the resource is in finite supply.

A related point is the need to correct income estimates in the national accounts if these show a distorted picture. As argued by a number of scholars, for example Usher (1981), Landefeld and Hines (1985), Eisner (1988), Hartwick (1988), Hartwick and Lindsey (1990), traditional national accounting practices do not properly measure activities based on exhaustible resources. 1/ Ideally, rent from such resources should not be treated as current income but rather as a change in the stock of wealth. Thus, to estimate current income correctly, the depletion of exhaustible resources should be deducted from the traditional income concept. Similarly, the permanent income deriving from holding oil assets should be added in.

In the Norwegian case, oil rents exceeded the normal return to labor and capital throughout the 1980s (Chart 1). 2/ In the first half of the decade, high oil prices and a steady expansion in output brought rents many times the normal compensation to labor and capital. With the fall in oil prices in 1986, the situation was drastically changed. The rent element remains considerably lower than in the mid-1980s. Nevertheless, in order to get an accurate picture, conventional data on overall nominal GDP and the

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1/ A similar argument can be made about pollution. Pollution can be seen as depreciation of a stock of environmental capital which should be included as a negative item in the calculation of national income. On this, see for example Hartwick (1990).

2/ The breakdown between rent income and normal compensation to labor and capital can be derived in several ways. The estimates in this paper were computed on the basis that the normal rates of return in the oil sector can be approximated by the rates of return in the non-oil sector.

current account still needs to be corrected. Data adjusted to exclude the rent element tell a very different story. The most striking difference perhaps relates to the current account (Chart 2). Although the current account as conventionally measured is in surplus, the adjusted current account remains in large deficit. However, taking into account the imputed income from oil wealth, the adjusted current account may actually be in balance.

Even in an economy without exhaustible resources, it is potentially misleading to focus narrowly on flows rather than stocks. For example, the effects of a current account deficit on future consumption possibilities depend on whether it finances consumption or investment. Stocks like national wealth and net foreign assets are what ultimately determine welfare in an intertemporal context. With exhaustible resources, this point is crucial. In order to determine whether or not the present non-oil deficits can be considered sustainable, what matters is not so much current income but rather the stock of wealth.

The value of Norway's oil wealth is subject to much uncertainty. In the absence of full-fledged markets for oil fields, the market value of oil and gas reserves has to be estimated. Total oil wealth can be broken down into two components. The first component is the present value of current and future oil rent income. The second component is the present value of the normal compensation to labor and capital net of investment expenditures. According to the so-called Hotelling (1931) valuation principle, the first component can, under certain assumptions, be approximated by the current rent per unit of output times the total reserves to be exploited. 1/ Calculating the second component is less straightforward as it is necessary to specify the entire future path of both output and investment. However, since the first component is likely to dominate, this may be less of a problem.

Geological investigations indicate that the total reserves of oil and gas on the Norwegian continental shelf may amount to some 20 years' production of oil and 100 years' production of gas at current production levels. Estimates along the lines above suggest that the total value of Norway's oil wealth in the beginning of 1991 may range between some 150 and 350 percent of non-oil GDP depending on the assumption for the 1991 oil

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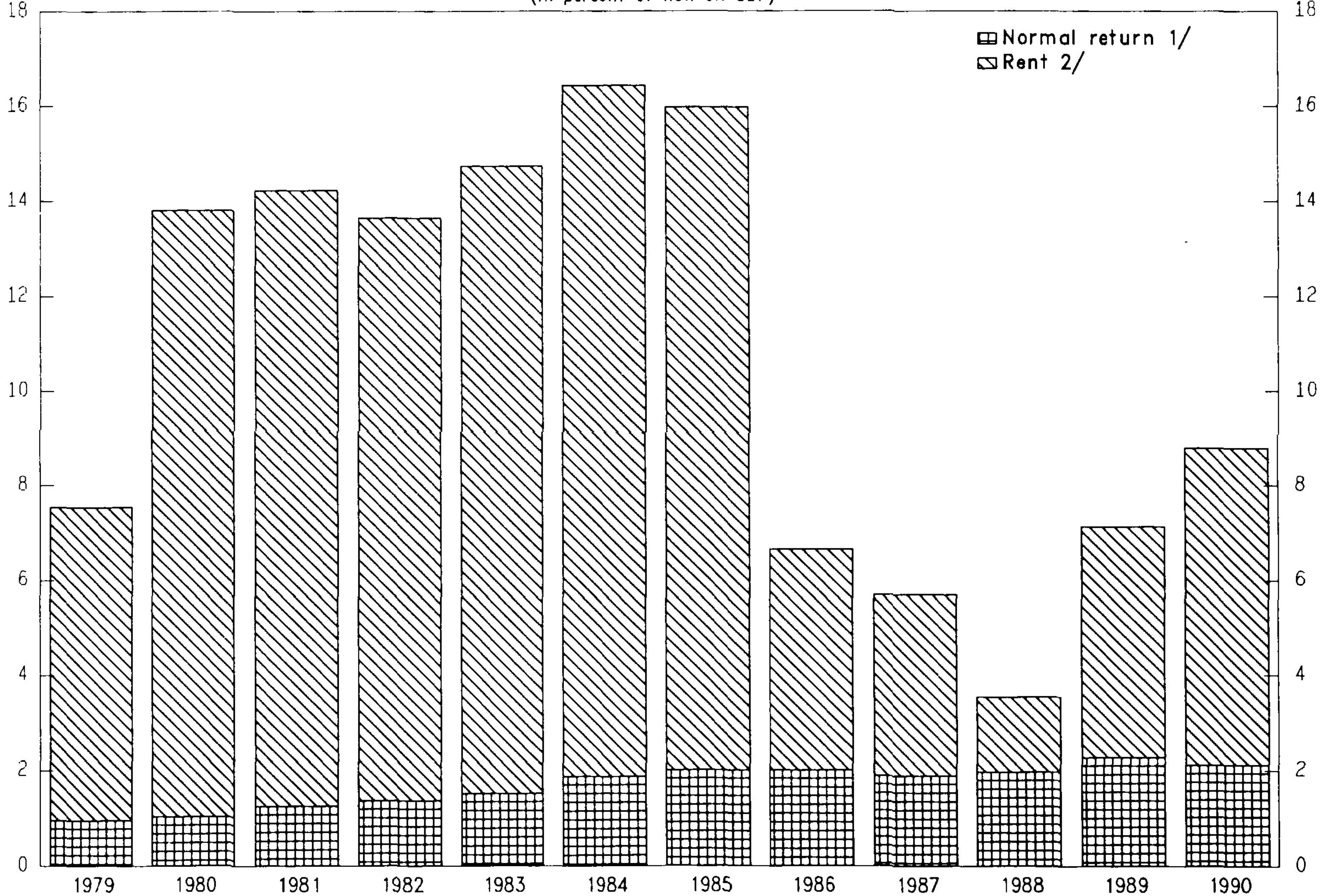
1/ Hotelling (1931) showed that a rational investor maximizing the present value of rent income will adjust production plans so that the expected rate of increase in the real rent per unit of output equals the expected real interest rate. Given constant returns to scale in both current and cumulative production, the unit value of the resource is equal to the spot price net of the marginal extraction cost. For a review of the Hotelling principle, see Miller and Upton (1985).

CHART 1
NORWAY

NET FACTOR INCOME FROM OIL ACTIVITIES

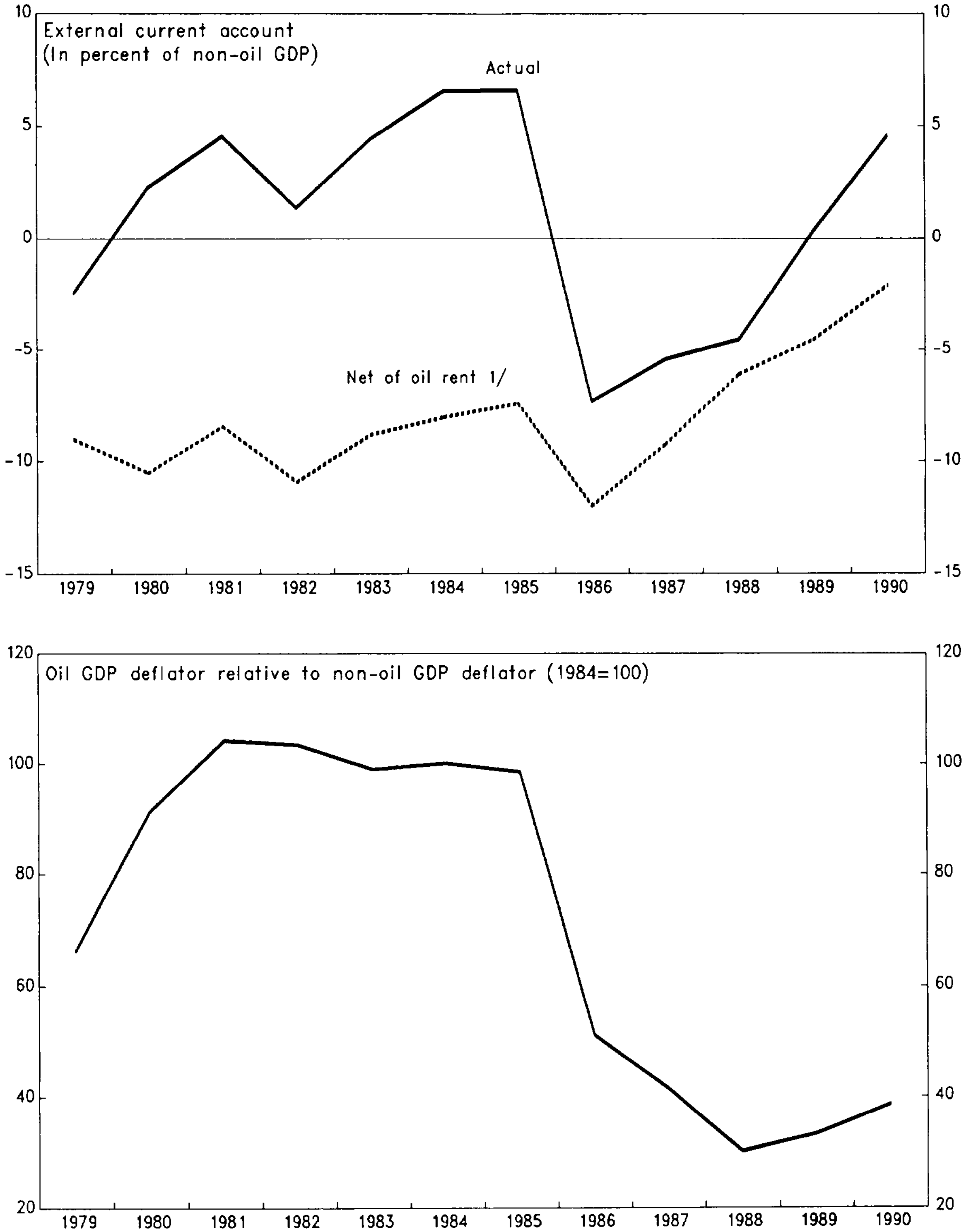
(In percent of non-oil GDP)



Source: Central Bureau of Statistics, National Accounts, various issues, and calculations by the author.

1/ Imputed return to labor and capital based on rates of return in the non-oil economy.
2/ Difference between oil sector net factor income and imputed return to labor and capital.

CHART 2
NORWAY
EXTERNAL CURRENT ACCOUNT AND REAL OIL PRICE



Source: Central Bureau of Statistics, National Accounts, various issues, and calculations by the author.

1/ Rent defined as the difference between oil sector net factor income and imputed return to labor and capital.

price (Chart 3). 1/ Similarly, with a major share of oil revenues in Norway accruing to the Government in the form of taxes, royalties and income from direct ownership participation, the Government's share may range between 120 and 280 percent of non-oil GDP. However, it would be a mistake to conclude that oil and gas reserves constitute the most important part of Norway's national wealth. The bulk derives from the productive capacity of the non-oil economy. Nevertheless, the expected return on oil wealth is large enough to cover significant non-oil deficits both for the Government and for the country as a whole.

As long as the use of oil revenues is based on a realistic assessment of total oil wealth, resource depletion may by itself not necessarily be a problem. Whether one prefers to hold assets in the form of oil in the ground or in the form of bonds and stocks is essentially a matter of portfolio selection. For example, in the Norwegian case, as long as financial assets are accumulated at the same rate as oil and gas reserves are depleted, there would be no need to worry about possible adverse consequences for future consumption possibilities. If spending of oil and gas revenues is confined to the return on oil wealth, the stock of wealth is kept unchanged. However, if this is not the case, national wealth is eroded.

It should be stressed that although a particular development may lead to a reduction in national wealth, this does not necessarily mean that it is undesirable. In a perfect economy with no externalities or distortions, saving and investment decisions reflect social opportunity costs. From the point of view of economic welfare, there is no basis for trying to influence private sector decisions to save and invest. However, in reality, government policies as well as market imperfections give rise to distortions which may warrant corrective actions. Still, it is important to note that the fact that saving is low does not in itself constitute a problem. The conclusion is that in order to determine whether or not low saving constitutes a problem, a careful analysis is needed. 2/

With the bulk of oil wealth in the hands of the public sector, Norwegian policymakers face a particularly difficult challenge in managing an important part of the country's wealth on behalf of both current and future generations. The natural starting point for a discussion about intergenerational equity is the standard model for optimal growth pioneered

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1/ Of course, these estimates are mainly to be seen as illustrative. While the Hotelling principle may not hold in practice, the basic point here is simply that oil and gas reserves can be treated as an asset which yields a return much like an ordinary financial asset.

2/ Whether or not possible discrepancies between saving and investment are a source of concern has been intensely debated in recent years. For a review of the arguments as well as the scope for government intervention, see Corden (1991).

by Ramsey (1928). 1/ In this model, current and future utility is maximized subject to an intertemporal budget constraint. Ramsey argued that utility discounting was unethical. Different generations ought not be treated differently just because of position in time. However, the model was later modified, both as a matter of convenience and for other reasons. 2/ A positive discount rate can be defended on the grounds of population growth, technical progress and uncertainty about the future. Later versions of the Ramsey model has usually allowed for utility discounting.

The Ramsey model is based on the utilitarian notion that equity between generations is adequately taken care of by an explicit comparison of the utility of each generation. Typical solutions to the Ramsey problem recommend that consumption be reallocated across generations until the discounted marginal utility is the same for all generations. It is not difficult to incorporate exhaustible resources in this framework. However, with or without a positive discount rate, the utilitarian approach may be open for criticism. Influenced by Rawls (1971), some scholars, notably Solow (1978), have proposed a different welfare criterion. Taking the least well-off generation as a standard, the current generation ought to leave behind sufficient resources to allow future generations at least the same level of consumption as the current generation.

As discussed by Hartwick (1977), in the absence of population growth and technical progress, this is possible only when the accumulation of reproducible capital exactly offsets the decline in the stock of exhaustible resources. Hartwick's rule constrains consumption to equal the real return on the sum of reproducible and exhaustible capital. With population growth and technical progress, the maximin criterion of constant consumption is difficult to maintain. As pointed out by Solow (1986), a simple extension of the Hartwick rule is still possible in which case consumption grows at the same rate as output. However, this, of course, means that one has to accept the idea that future generations are better off simply because they come later.

In the absence of uncertainty, determining the extra room for consumption over and above what is warranted by income from normal activities is straightforward. The extended Hartwick rule provides a helpful benchmark in this regard. To sustain the absolute level of oil

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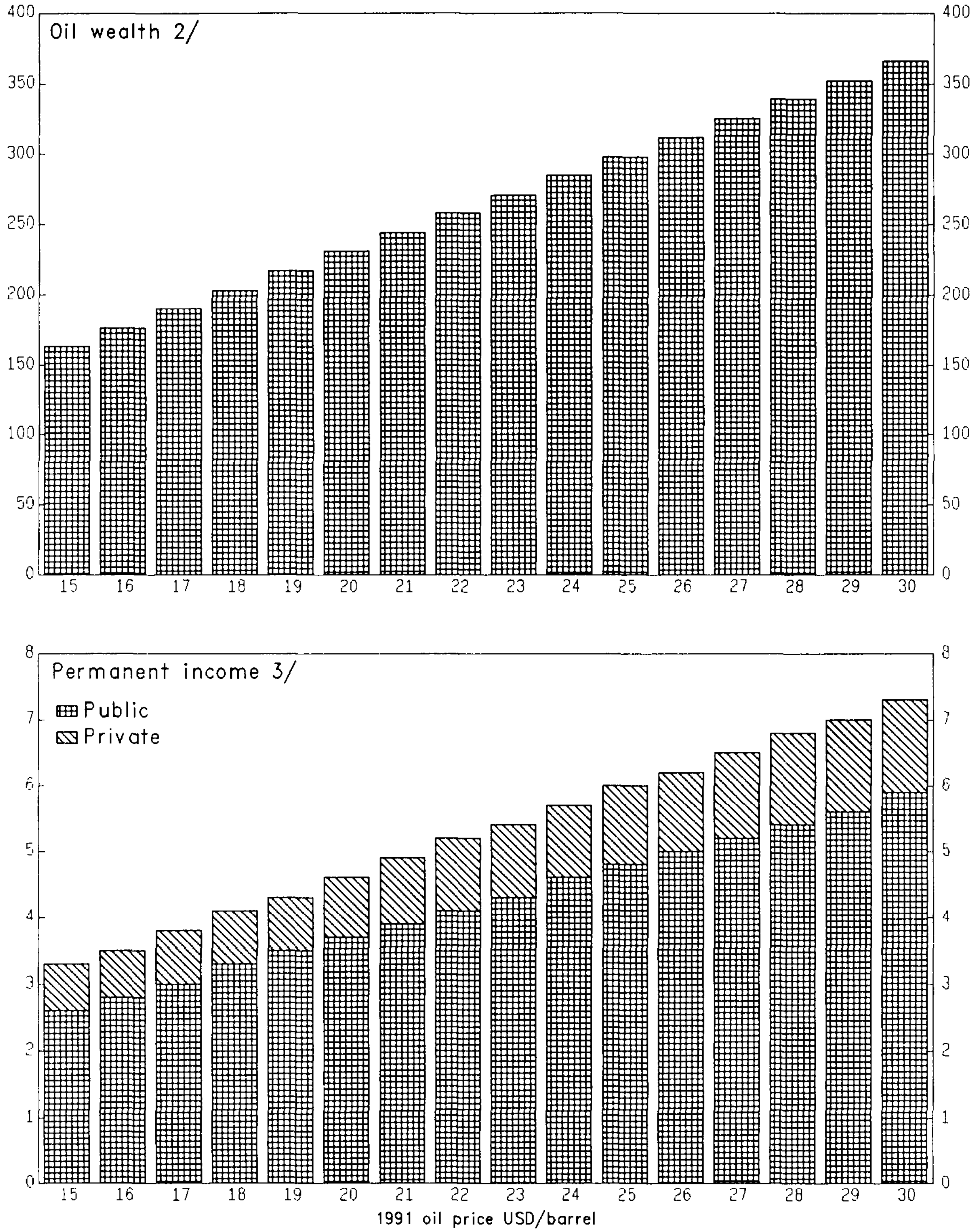
1/ For a review of the Ramsey model, see for example Blanchard and Fisher (1989).

2/ Without a positive discount rate, the problem of maximizing intertemporal utility becomes more difficult to handle. Ramsey solved the problem by postulating a "bliss point", an upper limit at which utility was saturated, and restated the objective to be the minimization of the accumulated deviations from this point. Another solution was suggested by Koopmans (1965) who arrived at a generalization of Phelps's (1961) famous golden rule theorem.

CHART 3
NORWAY
OIL WEALTH IN 1991 1/
(In percent of non-oil GDP)



Source: Calculations by the author.

1/ Based on total reserves equivalent to 20 years of oil and 100 years of gas. Assumes that the real rent per unit of output increases at a rate equal to the real interest rate.
2/ Present value of oil income minus investment expenditures.
3/ Real interest rate of 4 percent minus growth rate of real non-oil GDP of 2 percent times oil wealth.

wealth, only the return from oil wealth can be consumed. However, even if the absolute level is maintained, oil wealth may still deteriorate relative to non-oil GDP. If this is the case, although consumption can increase, the rate of growth is not sustainable. For a sustainable solution, the extended Hartwick rule requires a level of consumption such that it allows consumption and national wealth to increase in line with non-oil GDP.

Assuming for example a real interest rate of 4 percent (which is close to the latest World Economic Outlook assumption) and a value for oil wealth equivalent to 200 percent of non-oil GDP, the room for consumption consistent with an unchanged level of oil wealth is 8 percent of non-oil GDP. However, even if the absolute level is maintained, oil wealth may deteriorate relative to non-oil GDP, thus still violating the extended Hartwick rule. In a growing economy, the permanent income due to oil wealth is equal to the real interest rate minus the growth rate of output. With the same assumptions as above and under the additional assumption of a long-run growth rate of non-oil GDP of 2 percent, the room for consumption is equivalent to only 4 percent of non-oil GDP.

On this basis, the permanent income from total oil wealth adjusted for growth may range between 3 and 8 percent of non-oil GDP. Under reasonable assumptions about the value of oil wealth, a simple comparison between the permanent income from oil wealth and the non-oil current account deficit (defined as the difference between non-oil investment and non-oil saving) seems to suggest that the overall level of saving may well be, if not sustainable, at least close to sustainable at current oil prices (Table 2). By contrast, taking into account both the Government's share of total oil wealth and its financial assets, the non-oil government budget deficit seems unsustainably large. 1/ In order for the Government to meet its intertemporal budget constraint, the budget will eventually need to be tightened. If there is complete Ricardian equivalence, implying that a future increase in taxes is fully discounted by the private sector, this does not necessarily constitute a problem. 2/ However, in the absence of complete Ricardian equivalence, there is a case for fiscal consolidation.

Given the assumptions for the real interest rate and the long-run growth rate of non-oil GDP, the room for consumption due to oil wealth largely depends on the oil price. The above conclusions are therefore conditional on the particular oil price assumption. It should also be stressed that although the real interest assumption appears reasonable in

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1/ The calculation behind this proposition is in the spirit of Blanchard (1990). As it does not make use of projections, it is obviously only a very crude indication of the sustainability of present budgetary policies.

2/ Initially due to Ricardo, this argument was revived in a now classical article by Barro (1974). For a review of the Ricardian approach to fiscal policy and possible reasons for deviations from the case with complete tax-discounting, see Barro (1989).

Table 2. Indicators of External and Fiscal Sustainability for 1991

(In percent of non-oil GDP)

	Low	Medium	High
Oil wealth 1/	150.0	250.0	350.0
Imputed return 2/	2.9	4.8	6.7
Of which: Government	2.3	3.8	5.4
Difference between actual and sustainable non-oil external deficit 3/	1.1	-0.8	-2.7
Difference between actual and sustainable non-oil fiscal deficit 4/	5.6	4.0	2.5

Source: Calculations by the author.

1/ Present value of total oil income net of investment expenditures.

2/ Return on oil wealth adjusted for growth of non-oil GDP. Assumes a real interest rate of 4 percent and a growth rate of non-oil GDP of 2 percent.

3/ With the non-oil trade balance defined as the difference between non-oil GDP and non-oil domestic demand. Based on the growth-adjusted return on oil wealth minus net external debt.

4/ Based on the growth-adjusted return on government oil wealth plus government financial assets.

light of the more recent experience, it is high in a historical perspective. While the value of oil wealth should ideally be largely independent of the real interest rate assumption, this does not apply to permanent income which is highly sensitive to changes in this assumption. For example, with a real interest rate of 3 percent, the room for consumption due to oil wealth is cut in half. A further uncertainty concerns the amount of physical reserves.

Historically, official estimates of Norway's oil wealth have been subject to very large revisions (Table 3). In the beginning of the 1980s, oil wealth amounted to more than 500 percent of non-oil GDP. With the fall in oil prices in 1986, these estimates were sharply revised downwards. The uncertainty related to the value of oil wealth constitutes a major problem for the Norwegian economy. Indeed, with permanent income from oil wealth subject to large fluctuations, the question of sustainability must be constantly re-examined. Thus, in framing economic policy, it is important to pay sufficient attention to uncertainty. If there is uncertainty about oil prices, reserve estimates and production costs, there may be a need for precautionary saving over and above the level that a risk-neutral assessment would suggest. On the other hand, the uncertainty related to holding oil assets can be reduced through diversification. If national wealth can be freely reallocated across different assets, the presence of uncertainty should not affect the level of consumption.

III. Some Illustrative Calculations

In order to illustrate the points above, it may be useful to consider some simple numerical examples. For this purpose, a computable general equilibrium model has been calibrated to match estimates for the Norwegian non-oil economy in 1991 (see appendix for description). The model is based on forward-looking saving and investment behavior within a standard neoclassical framework along the lines of Abel and Blanchard (1983) and Blanchard (1985). While saving is modeled on the basis of overlapping generations of households with finite horizons, investment is modeled in accordance with Tobin's q-theory. Expectations about future variables are introduced by assuming rational expectations. In the absence of uncertainty, this implies perfect foresight. 1/ Examples of empirical

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1/ Considering the subject of this paper, this approach would seem to have obvious shortcomings. Given the particular specifications of the model, the solutions to the optimization problems underlying the investment and consumption functions are the same under uncertainty as under certainty. Technically, this is an attractive feature. Adding uncertainty generally makes the type of optimization problems from which the model is derived more difficult to solve. Nevertheless, from an economic point of view, allowing for an explicit role of uncertainty would certainly seem to be appealing in this context. However, in this case, analytical solutions tend to be either difficult to obtain or have other less desirable characteristics.

Table 3. Official Estimates of Oil Wealth

(*In billions of kroner at 1986 prices*)

	Oil wealth	Return	Non-oil GDP
1978	590	41	374
1979	1125	79	384
1980	1955	137	387
1981	2273	159	394
1982	2136	150	395
1983	2143	150	405
1984	1789	125	419
1985	1388	97	443
1986	694	49	457
1987	506	35	454
1988	413	29	441
1989	582	41	414
1990	1050	74	418

Source: Central Bureau of Statistics, *Økonomiske analyser*, various issues.

models which like the present model are based on intertemporal optimization include Leiderman and Razin (1989), McKibbin and Sachs (1989) and Persson and Svensson (1987).

One of the main attractions of this model is the emphasis on stocks. This is a natural consequence of modelling saving and investment decisions in a forward-looking manner. A central concept in the model is national wealth. This measure is defined as the present value of the economy's output less investment expenditure plus net foreign financial assets and the market value of natural resources. National wealth represents the economy's intertemporal budget constraint and is what ultimately determines the level of private and public consumption. The concept of national wealth can be thought of as an index measuring future consumption possibilities and is therefore an obvious policy target. A closely related concept is permanent consumption. Consistent with the extended Hartwick rule, permanent consumption refers to the level of consumption which allows consumption to grow at the same rate as output, which, as argued above, is a natural benchmark.

1. The issue of sustainability

It may be useful first to focus on total private and public consumption. In keeping with the spirit of the Ramsey model, total private and public consumption is a function of national wealth. 1/ The assumption is that investment and saving decisions are made according to an optimal program from the point of view of the economy as a whole. Ignoring distortions due to taxation as well as the effects of fiscal policy on private saving, the economy is treated as a single rational entity. As a further simplification, it is assumed that the capital stock equals its equilibrium value. In steady state, consumption, the capital stock and non-oil GDP all grow at the same rate. The long-run growth rate has been set to 2 percent while the real interest rate equals 4 percent. An important assumption concerns the initial value of oil wealth. On the basis of the estimates above, a range between 150 and 350 percent of non-oil GDP should cover all plausible values.

1/ Given the assumption that all income risks facing the economy can be offset through portfolio diversification, the solution to the optimization problem underlying the consumption function is the same under uncertainty as under certainty. The assumption is that national wealth can be reallocated freely across different assets. Optimal accumulation of uncertain assets is determined by the condition that the certainty equivalent rates of return should be equalized for all assets. For instance, the certainty equivalent net oil price should rise at a rate equal to the rate of return on risk-free assets. If national wealth can not be reallocated in this way, there may be a motive or precautionary saving, a possibility which, however, can not be considered within the present framework. For an analysis which does take risk into account explicitly, see Aslaksen and Bjerkholt (1985).

This range can be used to calculate lower and upper bounds for the level of permanent consumption consistent with a path according to which consumption and output would grow at the same rate (Chart 4). The difference between the lower and upper bounds is equivalent to 4 percent of non-oil GDP. It turns out that the actual level of consumption projected for 1991 is well within the two bounds. For which value of oil wealth is the actual level of consumption consistent with permanent consumption? Calculating backwards, the model yields an initial value of oil wealth equal to some 220 percent of non-oil GDP. According to the calculations above, this requires an oil price of about US$20 per barrel. For a higher oil price, the value of oil wealth is such that it would warrant a higher level of consumption than the actual level. Similarly, with a lower oil price, consumption would be too high for the saving rate to be sustainable.

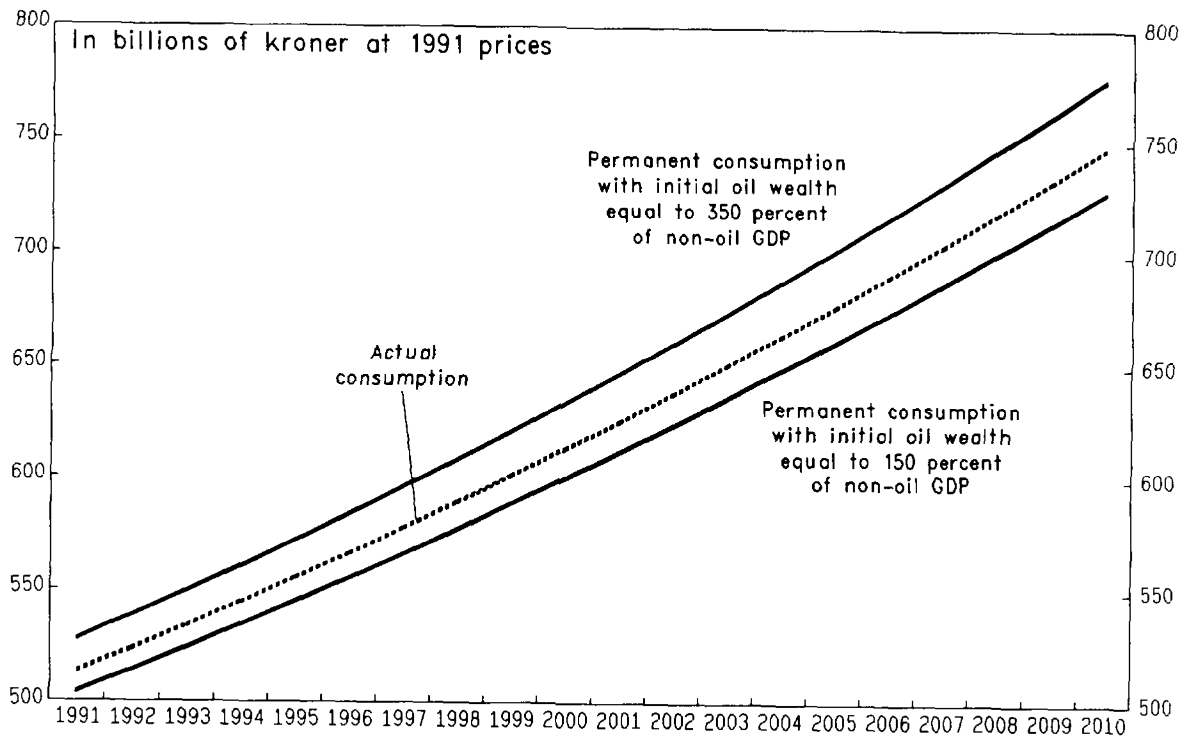
Another way of making the same point is through looking at the current account. Recall that permanent consumption is the level of consumption consistent with all variables including oil wealth growing at the same rate as non-oil GDP or, equivalently, consistent with an unchanged saving rate. This implies that the non-oil current account, measured including the permanent income from oil wealth and adjusted for productivity growth, must be in balance. While the economy receives interest income equivalent to the real interest rate times its net foreign assets, part of this income has to be saved in order to let net foreign assets grow at the same rate as output. According to this definition, a positive gap between permanent consumption and actual consumption means that the current account position is more than sustainable. In order to meet the economy's intertemporal budget constraint, a negative gap indicates that the current account needs to be strengthened.

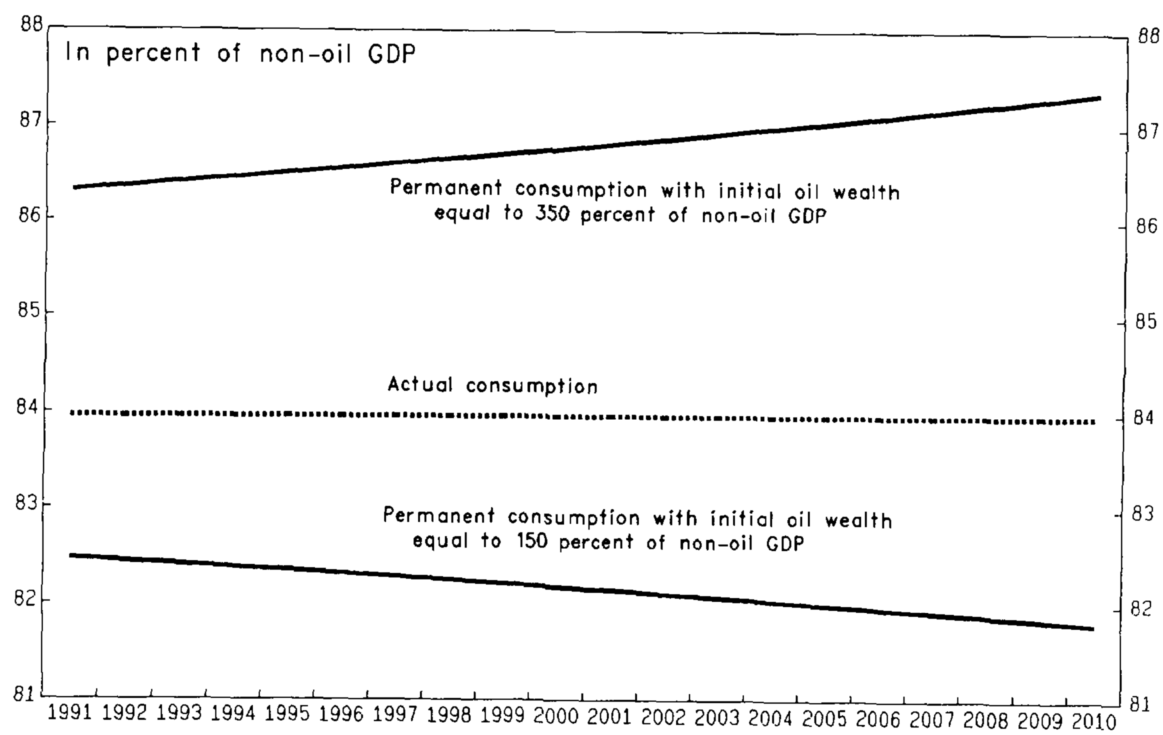
What are the long-run consequences of the present consumption level? Again, the answer to this question depends on the initial value for oil wealth. Consider the case where consumption grows in line with non-oil GDP. With an oil price higher than US$20 per barrel, permanent consumption is above actual consumption, in which case the extended Hartwick rule is more than fulfilled. At some point, the share of consumption in non-oil GDP will be adjusted upward. Similarly, with an oil price below US$20 per barrel, consumption must eventually be reduced. While movements in consumption and investment may cause temporary deviations, in steady state, all variables have to grow at the same rate, which in turn implies that the non-oil current account deficit including the permanent income from oil wealth and adjusted for growth, must be in balance.

2. The tradeoff between current and future consumption

Although the present share of consumption in non-oil GDP may deviate from its steady state level, this is not necessarily a problem from the point of view of economic welfare. Given the tradeoff between current and future consumption, a decision has to be made about the weights attributed to current versus future generations. One way of providing the basis for

CHART 4
NORWAY
PRIVATE AND PUBLIC CONSUMPTION





Source: Calculations by the author.

such a decision is to spell out the consequences of different consumption paths and let policymakers choose between these paths. Consider for example two consumption paths with consumption growing at a yearly rate of 1 and 3 percent respectively. In both cases, the initial value of oil wealth is 220 percent of non-oil GDP, the value for which permanent consumption initially is equal to actual consumption. In addition to the assumptions already made, terms of trade are assumed to be exogenously given, constant at the 1991 level.

In the first case, consumption grows at a lower rate than output, allowing for a continuous improvement in the current account and a buildup of external assets. As a result, national wealth and permanent consumption grow at a higher rate than output (Chart 5). While permanent consumption measures future consumption possibilities, this implies that relatively little weight is given to current generations. In other words, the extended Hartwick rule is more than fulfilled. By contrast, in the second case, consumption grows faster than output, thereby causing an erosion in national wealth and permanent consumption relative to a growth path where all variables grow at the same rate. In this case, current generations are treated more generously than the extended Hartwick rule would envisage. For any given planning horizon, this exercise can be repeated to trace out explicitly the tradeoff between consumption in the near future relative to consumption in the more distant future which may help in setting operational policy targets (Chart 6). With more elaborate calculations, it may be possible to translate policymakers' revealed preferences for a particular combination of current and future consumption into more precise policy requirements.

3. <u>The role of fiscal policy</u>

What is then the role of fiscal policy? There are basically two channels through which fiscal policy may affect private spending. For one thing, government tax and expenditure policies are often likely to be distortionary, having important implications both for the level and for the composition of saving and investment. But fiscal policy may also affect the private sector even without such distortions. One possibility is that households discount future taxes at a higher rate than the real interest rate. In the Blanchard (1985) setup, the difference between the two rates is determined by the length of the average household's planning horizon. The shorter the horizon is, the greater is the deviation from complete Ricardian equivalence. In this framework, fiscal policy affects aggregate demand through its effect on expected human wealth. With finite lifetimes, changes in taxation will have effects on consumption even if these changes are completely offset in the future.

Nevertheless, with sufficiently long horizons, the practical importance of this point may be rather limited. Further, the extreme version of the permanent income-life cycle model seems to be difficult to reconcile with actual consumption behavior. 1/ However, there may be a more direct link between consumption and fiscal policy than the framework with uncertain lifetimes would suggest. Although financial liberalization seems to have made consumption behave more like the permanent income-life cycle model would predict in most industrial countries, there is firm evidence that some households are subject to liquidity constraints. 2/ With some consumers being constrained by their current incomes, fiscal policy may have important implications for the behavior of private consumption and thereby also for national wealth.

In order to take liquidity constraints into account, the model includes two groups of consumers. The first group may be labelled permanent income consumers. Permanent income consumers determine their consumption on the basis of expected human and financial wealth. For simplicity, permanent income consumers are assumed to have infinite horizons. Thus, as far as this group is concerned, future taxes are fully discounted which implies complete Ricardian equivalence. The second group consists of current income consumers. Current income consumers set consumption equal to current labor income. For a satisfactory treatment of the interaction between private and public saving, it is important that fiscal policy be consistent with the intertemporal budget constraint of the public sector. The Government's intertemporal budget constraint requires that the present value of government expenditures equals the present value of taxes plus the Government's initial stock of wealth. With the share of government consumption in non-oil GDP assumed to remain unchanged, this is ensured by adjusting tax rates so that government assets are stabilized in terms of non-oil GDP. 3/

Consider now a situation where taxes initially are below the rate which would stabilize the ratio of government assets to non-oil GDP (Chart 7). The initial gap is assumed to be equivalent to about 2 percent of non-oil GDP. In order to satisfy the Government's intertemporal budget constraint, this gap must eventually be closed. Taxes are thus governed by a rule which requires half of the gap to be closed in each period. As for consumption behavior, two cases are considered. In the first case, the share of current income consumers is equal to 25 percent. As a result, despite the fact that

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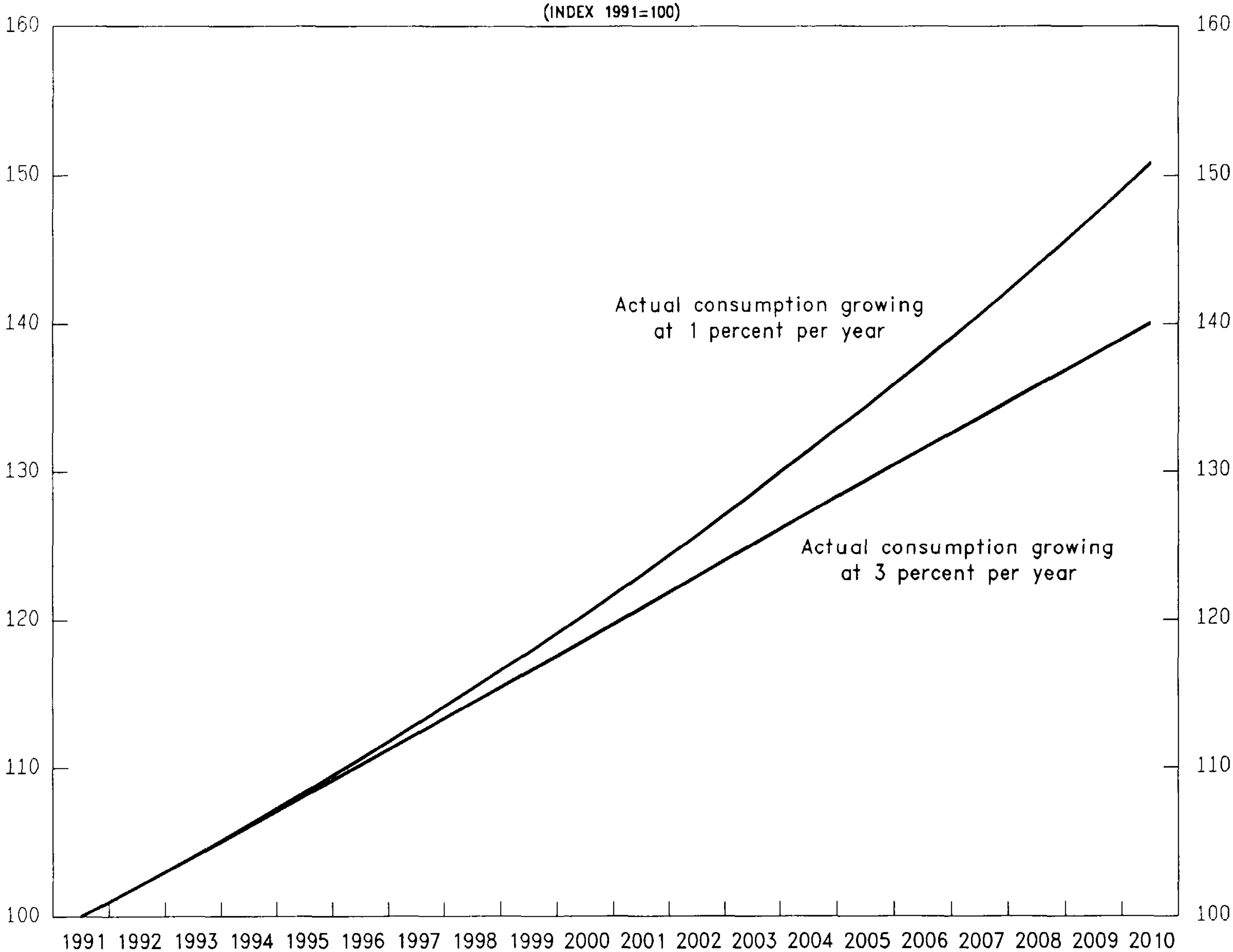
1/ In empirical studies, consumption is often found to be "excessively sensitive" to expected income changes. Similarly, it is also found to be "excessively smooth" with respect to unexpected changes in income. Both phenomena are inconsistent with household behavior based solely on unconstrained intertemporal optimization.

2/ Recent investigations into this matter include Campbell and Mankiw (1989) and Japelli and Pagano (1989).

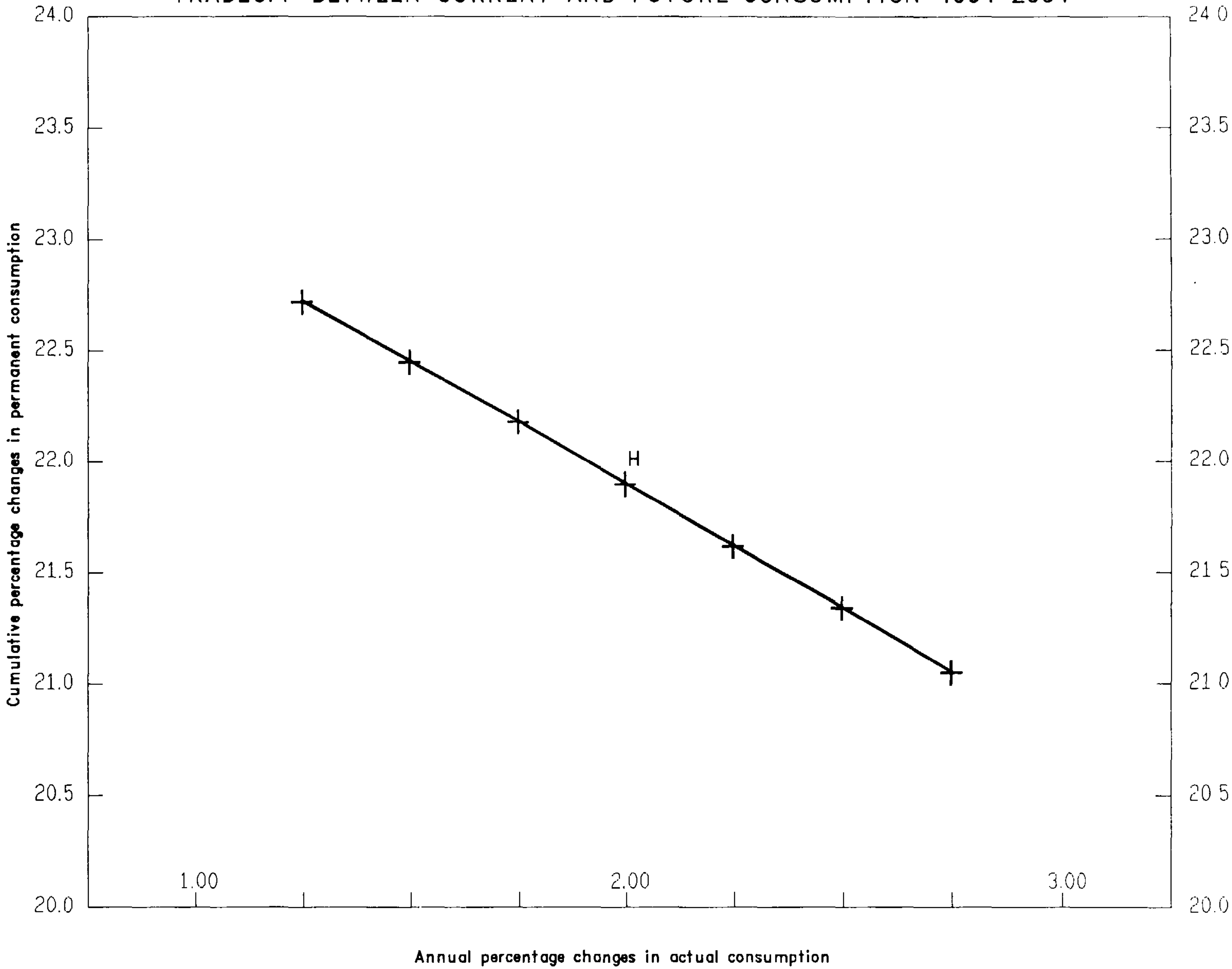
3/ A range of taxes can be considered within the framework of this model. The present version allows for a labor income tax, a corporate income tax, a capital income tax and a lump-sum tax. The latter falls solely on labor income and is adjusted to comply with the Government's intertemporal budget constraint.

CHART 5
NORWAY
PERMANENT CONSUMPTION
(INDEX 1991=100)



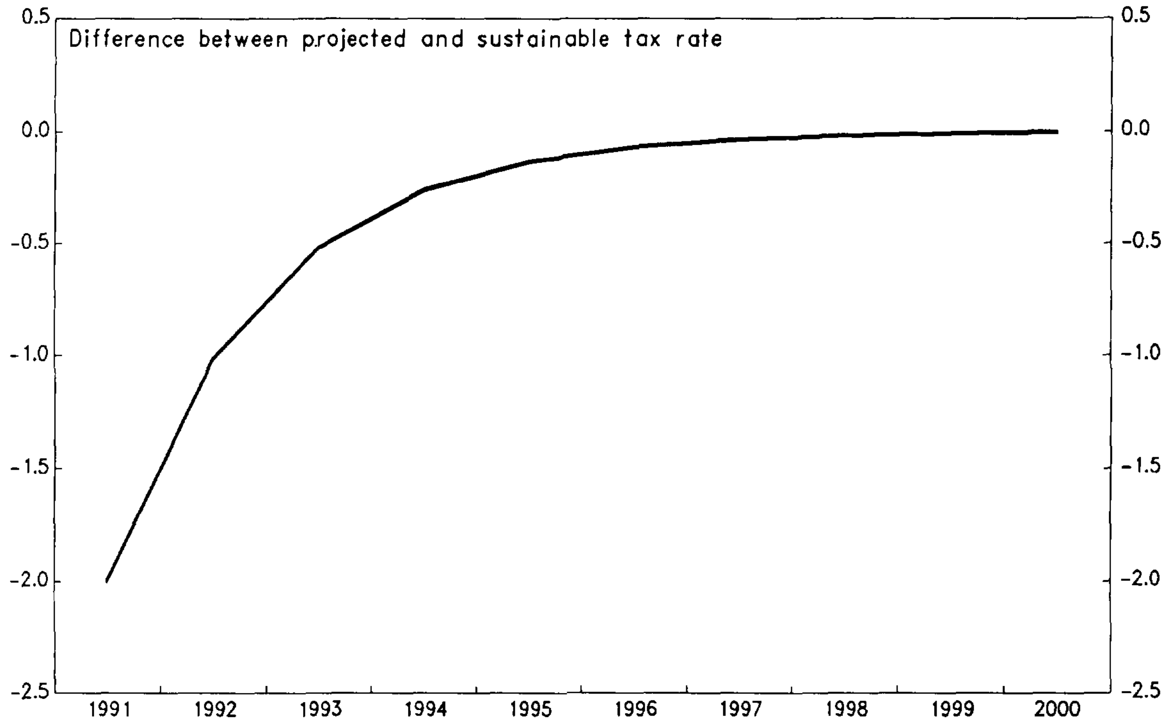
Source: Calculations by the author.

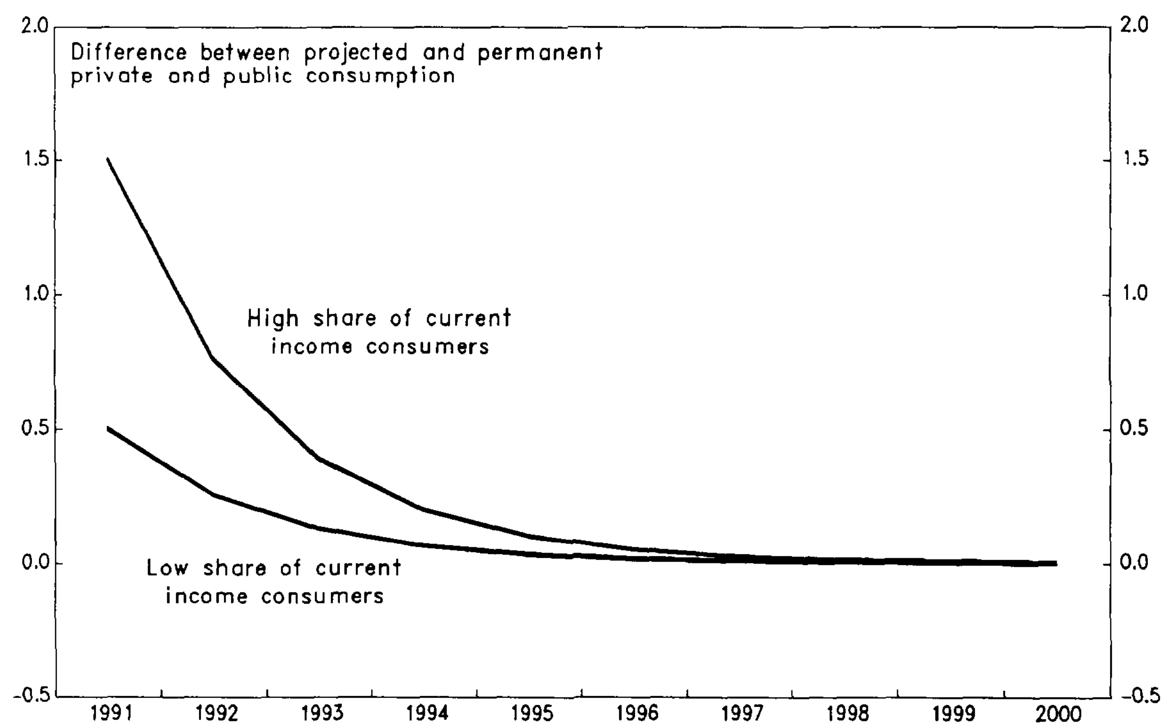
CHART 6
NORWAY
TRADEOFF BETWEEN CURRENT AND FUTURE CONSUMPTION 1991-2001



Source: Calculations by the author.

CHART 7
NORWAY
RELATION BETWEEN PUBLIC AND PRIVATE SAVING
(In percent of non-oil GDP)





Source: Calculations by the author.

the budget deficit is unsustainably large, there is relatively little harm done to future consumption possibilities as the difference between the projected and permanent values of private and public consumption is quite small. In the second case, the share of current income consumers is 75 percent. Because of the high share of current income consumers, the stance of fiscal policy has a stronger effect on consumption, causing the gap between the projected level of consumption and the level which is consistent with a growth path where consumption grows in line with non-oil GDP to widen.

Given that a growth path where consumption, output and national wealth is the optimal one, and the model is calibrated as if this were the case, the problem is simply that fiscal policy is too expansionary. If the tax gap could be closed, that is if the non-oil budget deficit could be reduced to a sustainable level, there would not be a problem. This is true regardless of the share of current income consumers. In the absence of other distortions, once fiscal policy is managed to keep the non-oil budget deficit on a sustainable level, there would be no need to worry about the overall level of saving. 1/ Consider the intermediate case where half of consumers are liquidity-constrained (Chart 8). Two possibilities are considered with 75 and 25 percent of the tax gap closed in each period. The faster the budget deficit is reduced, the faster is the gap between the projected and permanent values of private and public consumption closed. The longer the tax gap is allowed to persist, the more damage is done to future consumption possibilities.

4. The impact of changes in oil wealth

Any assessment of the appropriateness of a particular consumption path is subject to great uncertainty and must be updated continuously in light of new information. Focusing on the particular circumstances of the Norwegian economy, what are the implications of changes in the value of oil wealth? In the past, such changes have had a great impact not only on the stance of economic policies but also on the economy in general. As an illustration, consider for example an increase in the value of oil wealth due to a discovery of previously unknown reserves. 2/ The direct effect of this discovery would be an increase in national wealth and thus in permanent consumption. Although most of Norway's oil revenues are channeled through the public sector, the increase in government assets would affect the

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1/ Needless to say, with distortionary taxes, looking only at the size of the budget deficit is certainly not enough.

2/ What follows applies to an increase in oil prices as well. However, in addition to raising the value of oil wealth, higher oil prices would have a negative effect on activity in the non-oil economy through more expensive inputs. Such a supply shock is likely to result in a decrease in both output and employment which would make a calculation of the net effect more difficult.

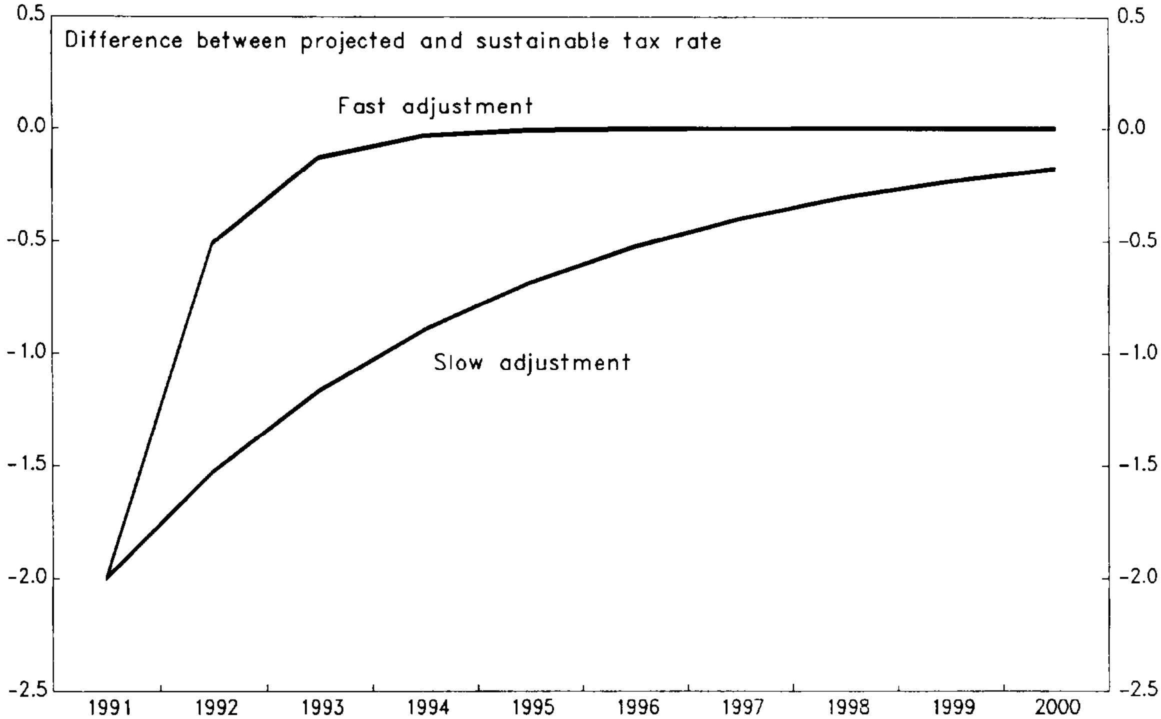
private sector as well. With the relaxation of the Government's intertemporal budget constraint, there would be scope for a reduction in taxation or an increase in public consumption. To the extent that the private sector would anticipate a future tax reduction, there would be an increase in private consumption as well.

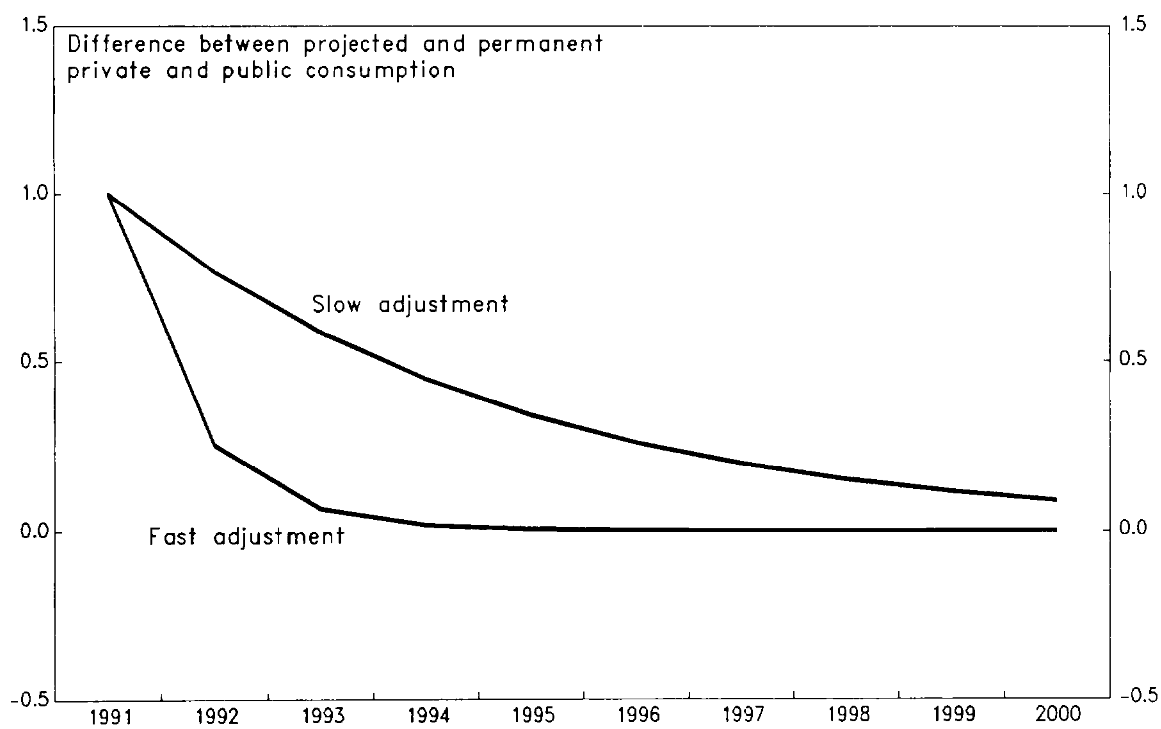
In the present example, it is convenient to start from a situation with a stable ratio between government assets and non-oil GDP. Private consumption is still partly a function of the current after tax labor income and partly a function of expected human and financial wealth with the propensity to consume out of wealth approximately equal to the real interest rate minus the long-run growth rate of output. In steady state, consumption and investment grow at the same rate as output which implies that the non-oil current account deficit including the permanent income from oil wealth is in balance. With domestically produced goods being imperfect substitutes to foreign goods, terms of trade are determined by market clearing. For simplicity, employment is assumed to be constant, implying that the main effect of demand shocks will be reflected mainly by movements in the relative price of domestic goods. In a more elaborate simulation, changes in demand may have effects both on employment and on productivity.

The present example illustrates the effects of an unanticipated increase in oil wealth from about 220 percent to 330 percent of non-oil GDP (Chart 9). As a result, there is an immediate increase in consumption. Because employment is held constant, there is little scope for an expansion in output. In order for the goods market to clear, there is an appreciation in the real exchange rate or, equivalently, an improvement in terms of trade. While this has a positive effect on profitability, there is an increase in investment as the capital stock is adjusted to a higher level. Nevertheless apart from raising the relative price of domestic goods, the main effect of the increase in domestic demand is a deterioration in the trade balance. The logic of this deterioration is simple. With the increase in oil wealth, the economy can afford to increase consumption of imported goods.

Two cases are considered. In the first case, 75 percent of all consumers make their decisions on the basis of current after-tax income. Further, fiscal policy is assumed to adjust rather slow to the relaxation of the Government's intertemporal budget constraint with only 25 percent of the tax gap closed in each period. By contrast, in the second case, 25 percent of all consumers are current income consumers while 75 percent of the tax gap is closed in each period. With these assumptions, the basic difference between these two cases is the speed of the adjustment of consumption to a higher level. This, in turn, implies a different response of investment as well. In the first case, the adjustment of consumption is relatively slow. The initial jump is due to the permanent income consumers. Were all consumers to behave like this, there would be an immediate increase in the level of adjustment after which consumption would rise at the same rate as non-oil GDP. This is more or less what happens in the second case.

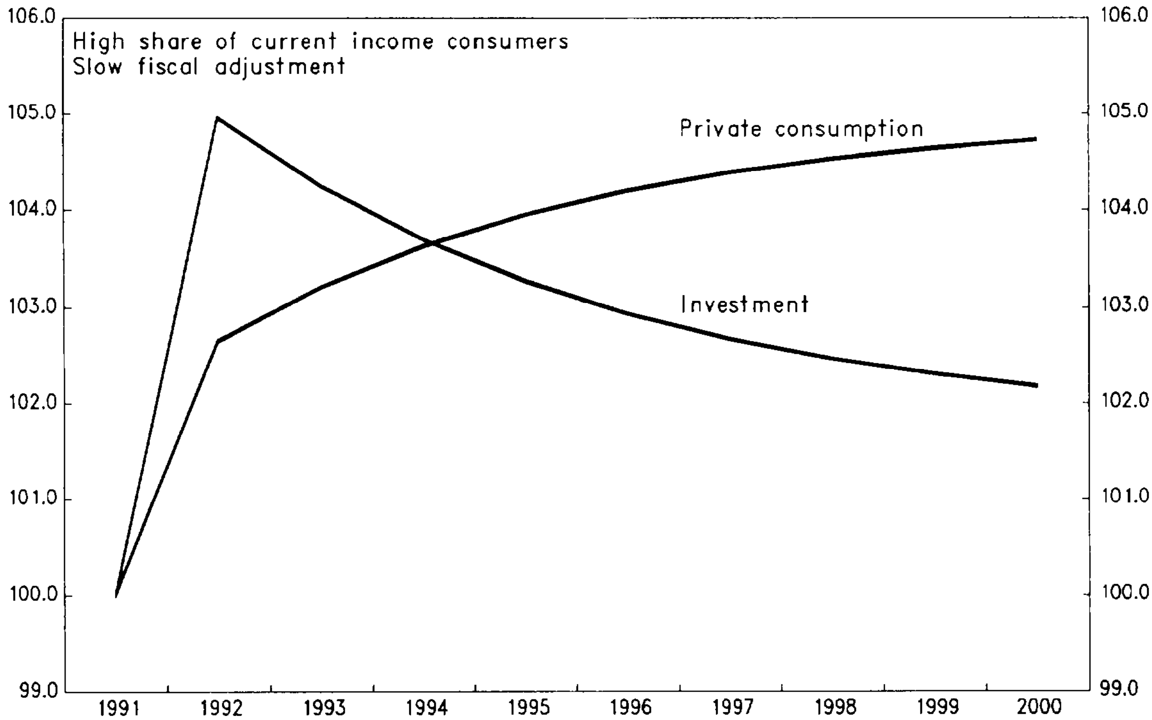
CHART 8
NORWAY
FISCAL POLICY AND FUTURE CONSUMPTION POSSIBILITIES
(In percent of non-oil GDP)

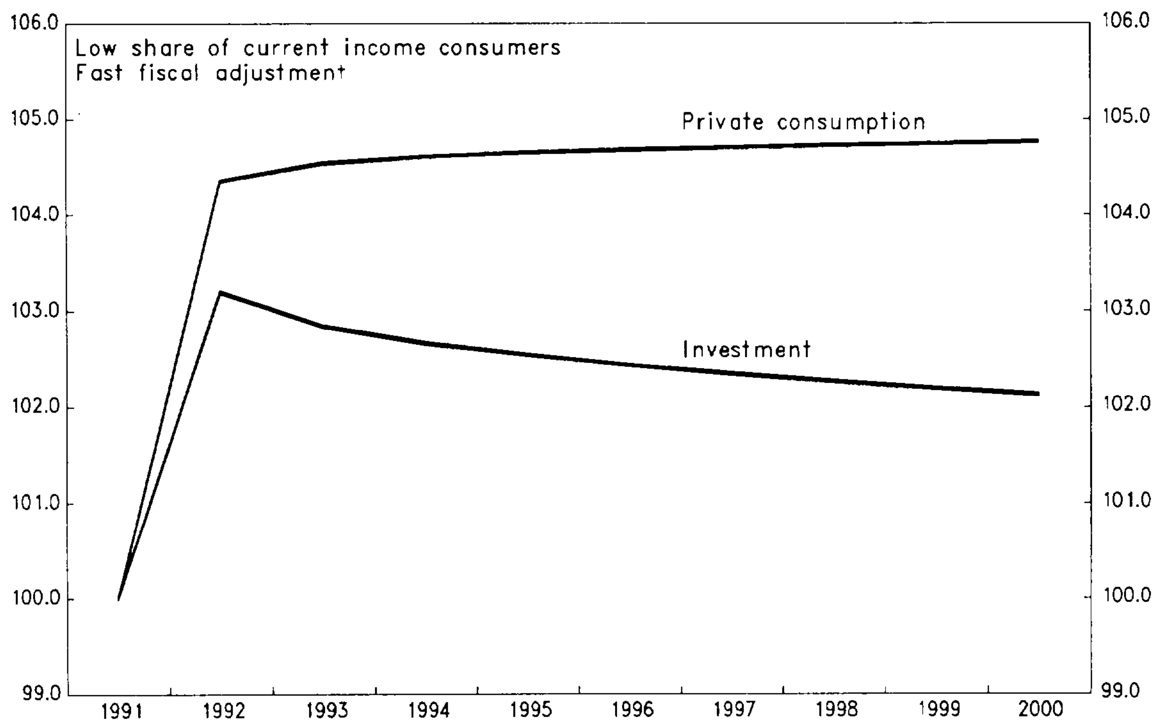




Source: Calculations by the author.

CHART 9
NORWAY
RESPONSE TO INCREASE IN OIL WEALTH
(Baseline=100)





Source: Calculations by the author.

What accounts for the behavior of investment? The increase in consumption pushes up the price of domestically produced goods. Because of the increase in the price of output relative to that of investment goods, investment becomes more attractive. In steady state, investment is determined by the requirement that the market value of the capital stock is equal to its replacement value. At the same time, terms of trade are fixed by the requirement that supply equals demand in the goods market. The important point here is that while firms are assumed to be price-takers, the entire path of investment is determined so as to maximize their stock market values. As firms demand a combination of foreign and domestic goods, investment and terms of trade are determined simultaneously. Despite the assumption of competitive pricing, firms take into account the impact of their own actions on output prices.

Now, in the first case, consumption rises slowly, initially causing relatively little upward pressure on output prices. Given the path for consumption, it is profitable to invest more in the beginning of the simulation period when consumption is relatively subdued. As consumption goes up and tends to put more upward pressure on output prices, investment becomes less attractive. In the second case, most of the increase in consumption is immediate. In this case, there is less scope for a reallocation of investment to the beginning of the period.

In terms of domestic demand, it does not matter much to what extent the adjustment of consumption is delayed. The relatively slow adjustment of consumption in the first case is more or less offset by the stronger initial response of investment. Therefore, the response of terms of trade and the trade balance is actually more or less the same in the two cases. 1/ The increase in oil wealth results in an expansion in consumption, thereby leading both to an appreciation in the real exchange rate and a deterioration in the non-oil current account. Similarly, a reduction in oil wealth would reduce consumption and tend to depress both investment and output. However, the impact of such shocks can be at least partly offset by appropriate fiscal policy measures.

In order to add more realism to the simulation, one may consider a number of modifications the most important being a stronger link between demand and output through effects on employment and productivity.

1/ Of course, these conclusions are conditional upon the particular configuration of parameters which has been chosen. Experiments based on other parameter values will yield different results. For example, if the share of domestic goods in investment is sufficiently small, the tendency for investment to offset the response of consumption disappears. Further, with exogenous terms of trade, there may be no reason for investment to be affected at all. However, if movements in consumption have effects on capacity utilization, investment may be affected even in this case.

Although such a modification would provide for more realism, the basic conclusions are unlikely to change. Changes in the value of oil wealth are likely to generate movements in domestic demand. Given that fluctuations in demand are likely to cause fluctuations in output, an increase in oil wealth can be expected to lead to an increase in employment. However, to the extent that the expansion in output is less pronounced than that of demand, there would be a real appreciation in the exchange rate and a deterioration in the non-oil trade balance. While a more pronounced output response would tend to enhance these effects, a greater sensitivity of consumption with respect to changes in activity would tend to reduce them.

Summing up, the logic of this example is as follows. An increase in oil wealth serves to relax the Government's intertemporal budget constraint. Over the longer run, there is an increase in government expenditures or a reduction in taxes. Since the Government is bound by its intertemporal budget constraint, an increase in oil wealth will result in lower taxes in the future. With forward-looking consumers, an expected future tax reduction implies an increase in household wealth, thereby causing an increase in private consumption. In the extreme case with infinite horizons and no liquidity constraints, there is a complete offset. It does not matter to what extent the Government chooses to delay the reduction in taxes. In the more realistic case, with consumption partly being constrained by current after-tax income, there is scope for fiscal countermeasures. Given that fiscal policy has such a role, there is no way around making judgements about the intertemporal allocation of consumption on behalf of the private sector.

Finally, keeping in mind the caveats listed above, it is tempting to try to apply the story in this section to actual developments in the Norwegian economy. Although in the opposite direction, the fall in oil prices in 1986 caused an adjustment process very much like the simple simulation of an increase in oil wealth considered above. Thus, with a reduction in oil wealth, fiscal policy was tightened. With the reduction in the economy's purchasing power, there was a decrease in private consumption. This, in turn, caused a reduction in output, employment and investment. At the same time, a disinflationary process was initiated which eventually reversed the upward trend of the real exchange rate. Given the dependency on oil, one of the major tasks of economic policy is to smooth the adjustment to such shocks in oil prices.

IV. Concluding Remarks

Taking Norway as a point of departure, this paper provides a discussion of the macroeconomics of exhaustible resources. The exploitation of exhaustible resources differs from other economic activities in that the revenues that are generated partly represent a depletion of wealth, or equivalently, economic rent. In an economy based on natural resources, traditional national accounting concepts are typically misleading. To provide a more meaningful picture, the rent income from exhaustible resources should be deducted from the traditional income concept. Similarly, in order to get a fair idea of how much the economy can afford to spend, the permanent income from natural resources should be added in.

The reserves of oil and gas represent an important part of Norway's national wealth. Together with other components of national wealth, oil wealth is a major determinant of current and future consumption possibilities. Taking into account the permanent income from oil wealth, the non-oil current account deficit can register significant deficits without an erosion in national wealth. With the bulk of Norway's oil wealth owned by the public sector, the same argument can be made about the non-oil government budget balance.

In an economy based on exhaustible resources, long-term sustainability is an obvious issue. In the Norwegian case, to what extent do the present non-oil deficits in the current account and the government budget have to be reduced in the longer run? Given the uncertainties involved, such a question is difficult to answer. Nevertheless, at present, while the non-oil current account deficit seems to be more or less sustainable, the non-oil deficit in the government budget seems to be unsustainably large and may thus need to be reduced in the longer run.

Although the present deficits may be unsustainable, this does not necessarily mean that they are undesirable. From an economic point of view, it might be argued, one consumption path, sustainable or not, may be just as good as the other. Of course, there are reasons to believe things are not that simple. Particularly, because of government policies or market failures, private saving and investment decisions may be distorted. While the first best policy is to address such distortions directly, if this is not possible, the overall level of saving may still be a legitimate policy objective. In addition, unless all consumers behave in a Ricardian manner, there is a direct link between fiscal policy and future consumption possibilities.

As far as sustainability is concerned, simple indicators can go a long way. However, to determine whether or not a particular situation is sustainable is usually not enough. This paper outlines some ideas how to treat problems related to exhaustible resources in a macroeconomic context. Even in an economy without exhaustible resources, a narrow focus on the current account, however defined, is economically not very meaningful. The paper argues that instead of focusing on the current account, one should focus on national wealth. Being the economy's intertemporal budget constraint, national wealth is what ultimately determines the room for public and private consumption. National wealth measures future consumption possibilities and is therefore a natural policy target. On the basis of a dynamic general equilibrium model, the basic approach is demonstrated with the help of some simple exercises.

Model Description

This section provides a brief description of a small dynamic intertemporal general equilibrium model of saving and investment fully consistent with forward-looking optimizing firms and households. In its basic form, the model is a one-sector model of a small open economy. The model can, however, be simulated both with exogenous and endogenous terms of trade. With variable terms of trade, the model treats consumption and investment as composite goods, consisting both of home goods and foreign goods. The present version of the model assumes that domestic and foreign securities are perfect substitutes. With a perfectly fixed exchange rate and perfect capital mobility, the economy faces a given world market interest rate. Various wage formation rules are possible. In this paper, employment is assumed to be exogenously given and real wages are assumed to adjust accordingly. Expectations about future variables are introduced by assuming rational expectations. In the absence of genuine uncertainty, this implies perfect foresight.

1. Firms

In each period t, the representative firm produces output Y_t with a Cobb-Douglas production function using capital K_t and labor L_t as inputs. 1/ The process driving productivity A_t is not necessarily smooth and may include cyclical changes in capacity utilization. However, in the long run, productivity is assumed to grow in line with a deterministic trend capturing exogenous technical progress. 2/ The firm's production function is:

$$Y_t=A_tK_t^{\alpha}L_t^{(1-\alpha)} \tag{1}$$

As in Hayashi (1982), there are convex installation costs, implying that the firm only gradually adjusts its capital stock to the desired level. While real net investment J_t is simply the change in the capital stock, real gross investment I_t also includes installation costs $\beta(J_t/K_t)J_t$ and

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1/ The firm's production technology can easily be modified to incorporate intermediate goods. Gross output may then be a function of value added and intermediate inputs.

2/ Allowing for endogenous technical progress is an interesting extension which may add further realism to the model. A simple way of doing this is to link productivity to investment.

depreciation δK_t. 1/ With these assumptions, the firm's net and gross investment can be written as follows:

$$J_t=K_{t+1}-K_t \tag{2}$$

$$I_t=[1+\beta(J_t/K_t)]J_t+\delta K_t \tag{3}$$

In carrying out its investment plans, the representative firm uses a combination of domestic and foreign goods. The composite good is a linearly homogenous CES function in domestic and foreign investment goods. The exact form of this function depends on the value of the elasticity of substitution between the two goods. In the special case with a unitary elasticity of substitution, it is a Cobb-Douglas function. With superscripts D and F denoting domestic and foreign goods respectively, the composite investment good technology is:

$$\begin{aligned} I_t&=[\epsilon_1^{(\frac{1}{\epsilon_2})} I_t^{D\,(1-\frac{1}{\epsilon_2})}+(1-\epsilon_1)^{(\frac{1}{\epsilon_2})} I_t^{F\,(1-\frac{1}{\epsilon_2})}]^{(\frac{\epsilon_2}{\epsilon_2-1})} \\ &=\epsilon_1^{-\epsilon_1}(1-\epsilon_1)^{(\epsilon_1-1)} I_t^{D\,\epsilon_1} I_t^{F\,(1-\epsilon_1)} \quad for\ \epsilon_2=1 \end{aligned} \tag{4}$$

In the beginning of each period, the firm pays dividends D_t equivalent to its net cash flow:

$$D_t=P_t^D Y_t-W_t L_t-P_t^I I_t \tag{5}$$

where P_t^D is the price of output, W_t is the nominal wage and P_t^I is the price index of the composite investment good. Under perfect foresight, the returns on stocks and bonds must be equalized. The total return on an investment in stocks E_t including capital gains is $(1+r_{t+1})D_t+(E_{t+1}-E_t)$ which should be equal to the return on an investment of the same amount in bonds $r_{t+1}E_t$. Setting up this arbitrage condition and solving it forward yields the value of the firm as the present value of its net cash flow:

1/ Defining the installation cost function in terms of changes in the capital stock is convenient since it opens up for the possibility that installation costs are zero in steady state. The steady state rate of growth of productivity is simply added to the depreciation rate. The installation cost function is then be defined in terms of changes in the capital intensity rather than the capital stock.

$$E_t=\sum_{t=s}^{\infty}(1+r_t)\prod_{v=t}^{s}(\frac{1}{1+r_v})D_s \quad (6)$$

The firm is assumed to choose production and investment plans so as to maximize its stock market value given rationally expected input and output prices. 1/ Maximizing the present value of the firm's net cash flow subject to the difference equation for the capital stock yields the following first order conditions for an optimal investment program:

$$J_t=[((q_t/P_t^I)-1)/2\beta)]K_t \quad (7)$$

$$q_t=(\frac{1}{1+r_{t+1}})[q_{t+1}+\alpha P_{t+1}^D A_{t+1}K_{t+1}^{(\alpha-1)}L_{t+1}^{(1-\alpha)}-P_{t+1}^I(\delta-\beta(\frac{J_{t+1}}{K_{t+1}})^2)] \quad (8)$$

The specification of the firm's maximization problem implies that investment depends on the value of an installed unit of capital relative to its replacement cost q_t (Tobin's average and marginal q).

The first order condition for employment defines employment as a function of output and the real product wage. Although the supply of labor is not explicitly modeled, several types of wage formation processes can be examined. 2/ In the simple case when employment is exogenously given, the real product wage is equal to the marginal product of labor so that:

$$W_t=(1-\alpha)P_t^D K_t^{\alpha}L_t^{-\alpha} \quad (9)$$

The first order conditions for the optimal combination of domestic and foreign goods in the investment composite yields a solution which defines the firm's demand for each good as a function of gross investment and relative prices. By Shephard's lemma, the demand for each good can be written:

1/ This is in general a stochastic problem. However, given constant returns to scale and perfect competition, the solution to the firm's optimization problem is the same under uncertainty as under certainty.

2/ The process driving employment can take different forms depending on the flexibility and speed of adjustment in the labor market. Making employment endogenous is an important extension which, however, would make the model more difficult to solve.

$$I_t^D=\epsilon_1(P_t^I/P_t^D)^{\epsilon_2}I_t \qquad (10)$$

$$I_t^F=(1-\epsilon_1)(P_t^I/P_t^F)^{\epsilon_2}I_t \qquad (11)$$

where the price index for the composite investment good is:

$$\begin{aligned}P_t^I&=[\epsilon_1 P_t^{D\ (1-\epsilon_2)}+(1-\epsilon_1)P_t^{F\ (1-\epsilon_2)}]^{(\frac{1}{1-\epsilon_2})}\\&=P_t^{D\ \epsilon_1}P_t^{F\ (1-\epsilon_1)}\ \textit{for}\ \epsilon_2=1\end{aligned} \qquad (12)$$

For an initial value of the capital stock and a sequence of exogenous variables, the firm's maximization problem can be solved to yield a sequence of production, investment, wages, dividends and stock market values. The aggregation of individual firms is straightforward so that all variables for the representative firm apply to the production sector as a whole.

2. Households

There are overlapping generations of households with finite expected lifetimes. Following Blanchard (1985), each household faces a given probability of survival from the current period to the next π so that the expected lifetime is equal to $1/(1-\pi)$. The fact that households have finite horizons implies that they pay a risk premium in the capital market which means that Ricardian equivalence may not hold in the model. The representative household has an instantaneous utility function with a constant rate of intertemporal substitution and maximizes an intertemporal utility function with the following form:

$$\sum_{s=t}^{\infty}(\frac{\pi}{1+\rho})^{s-t}U_s \quad U_s=\frac{C_s^{1-1/\sigma}}{1-1/\sigma}=\ln C_t\ \textit{for}\ \sigma=1 \qquad (13)$$

Similar to investment, consumption C_t *is a composite good consisting* both of domestic and foreign goods. The consumption composite is a linearly homogenous CES function in domestic and foreign goods. The exact functional form depends on the value of elasticity of substitution between the two goods. The household's preferences for the two goods can be described in the following manner:

$$C_t=[\mu_1^{(\frac{1}{\mu_2})} C_t^{D\,(1-\frac{1}{\mu_2})}+(1-\mu_1)^{(\frac{1}{\mu_2})} C_t^{F\,(1-\frac{1}{\mu_2})}]^{(\frac{\mu_2}{\mu_2-1})} \tag{14}$$

$$=\mu_1^{-\mu_1}(1-\mu_1)^{(\mu_1-1)} C_t^{D\,\mu_1} C_t^{F\,(1-\mu_1)} \quad for\ \mu_2=1$$

The representative household receive dividends and wages from the productive sector and pays lump-sum taxes to the government. The household's dynamic budget constraint is:

$$F_{t+1}=(\frac{1+r_{t+1}}{\pi})[F_t+W_tL_t-T_t-P_t^CC_t] \tag{15}$$

where F_t is the household's holdings of financial assets, T_t is taxes net of transfers to the government and P_t^C is the price index of the composite consumption good.

Although there is no aggregate uncertainty in this model, the lifetime of each individual household is not known with certainty. This raises both the rate at which future utility is discounted and the effective rate of interest faced by the representative household. With a probability to survive to the next period less than one, $\pi<1$, the representative household pays a risk premium in the capital market. The reasoning behind is based on the idea that households can buy insurance contracts which allow for negative life insurance. This means that insurance companies are prepared to pay a premium to households currently alive in exchange for receiving their entire assets in case of death.

In each period t, insurance companies receive a fraction of the household sector's total financial assets equal to $(1-\pi)$. These payments are invested in bonds carrying a real interest rate r_{t+1} so that total revenues become $(1+r_{t+1})(1-\pi)$ times the household sector's total financial assets. At the same time, insurance companies pay premiums to the fraction π of all households still alive. Total expenditures of the insurance companies are equal to the premium rate times total financial assets of all surviving households. With zero profits in the insurance industry, the premium rate turns out to be $(1+r_{t+1})(1-\pi)/\pi$. Adding the premium rate to the interest rate factor $(1+r_{t+1})$ yields the effective discount rate factor $\pi/(1+r_{t+1})$. Solving the dynamic budget constraint forward yields the intertemporal budget constraint:

$$\sum_{s=t}^{\infty}(\frac{1+r_t}{\pi})\prod_{v=t}^{s}(\frac{\pi}{1+r_v})P_s^CC_s=F_t+H_t \tag{16}$$

where human wealth H_t is defined as the present value of labor income:

$$H_t=\sum_{t=s}^{\infty}\left(\frac{1+r_t}{\pi}\right)\prod_{v=t}^{s}\left(\frac{\pi}{1+r_v}\right)[W_sL_s-T_s] \tag{17}$$

In case the household has free access to the credit market, maximizing future discounted utility subject to the intertemporal budget constraint yields a solution that defines consumption as a function of total household wealth:

$$C_t=R_t[(F_t+H_t)/P_t^C] \tag{18}$$

where R_t is the time-dependent propensity to consume out of total household wealth. 1/ The consumption propensity is a function of the expected paths of the real interest rate and the price index for the composite consumption good:

$$R_t=\frac{1}{\sum_{s=t}^{\infty}\left(\frac{\pi}{1+\rho}\right)^{(s-t)\sigma}\left[\left(\frac{\pi}{1+r_t}\right)\prod_{v=t}^{s}\left(\frac{1+r_v}{\pi}\right)\right]^{(1-\sigma)}\left(\frac{P_s^C}{P_t^C}\right)^{(1-\sigma)}} \tag{19}$$

In the special case with infinite horizons and a unitary intertemporal elasticity of substitution so that $\pi=\sigma=1$, the consumption propensity is approximately equal to the rate of time preference ρ. Assuming further that the rate of time preference equals the real interest rate adjusted for growth, that is $\rho=(1+r_{t+1})/(A_{t+1}/A_t)-1$, the consumption propensity is equal to $(1-(A_{t+1}/A_t)/(1+r_{t+1}))$. This formulation fulfills the extended Hartwick rule and is also consistent with Ricardian equivalence.

A large body of evidence suggests that aggregate consumption may only partly be determined along the lines of permanent income-life cycle model with the prime explanation being that some households may face liquidity

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1/ Given that income is diversifiable, the solution to the household's optimization problem is the same under uncertainty as under certainty. However, in the general case when uncertainty has a precautionary effect on consumption, the optimization problem is more difficult to handle. For the constant relative risk aversion utility function above, a closed form solution is not possible. One case that can be solved is that of constant absolute risk aversion. This case has, on the other hand, the undesirable property of allowing the marginal utility of consumption to be finite at zero consumption.

constraints. 1/ A simple way of taking this fact into account is to introduce a second group of consumers who consume a constant fraction out of current labor income. With a fraction λ of labor income accruing to current income consumers, the consumption function is modified as follows:

$$C_t=\lambda(W_tL_t-T_t)+R_t[(F_t+(1-\lambda)H_t)/P_t^C] \tag{20}$$

Maximizing instantaneous utility with respect to consumption of domestic and foreign goods defines consumption demand for each good. As in the case of investment, the share of each good in the consumption composite depends on relative prices:

$$C_t^D=\mu_1(P_t^C/P_t^D)^{\mu_2}C_t \tag{21}$$

$$C_t^F=(1-\mu_1)(P_t^C/P_t^F)^{\mu_2}C_t \tag{22}$$

where the price index of the consumption composite is:

$$\begin{aligned} P_t^C&=[\mu_1P_t^{D\ (1-\mu_2)}+(1-\mu_1)P_t^{F\ (1-\mu_2)}]^{(\frac{1}{1-\mu_2})} \\ &=P_t^{D\ \mu_1}P_t^{F\ (1-\mu_1)} \quad \text{for } \mu_2=1 \end{aligned} \tag{23}$$

The representative household's decisions result in time paths for private consumption and financial assets. The aggregation of individual households goes as follows. Assume for simplicity that the population consists of an infinite number of cohorts with the initial size $(1-\pi)$. The size of each generation in period s is thus $(1-\pi)\pi^{(s-t)}$ which means that the total population is normalized to one. Since composite consumption is linear in total wealth, total consumption is simply the number of households times consumption of the representative household. The same applies to human wealth. Aggregate human wealth is the present value of aggregate labor income discounted at the risk-adjusted rate. While the consumption propensity and the discount factor applied to labor income are unaffected by aggregation, the effective rate of return on private assets is not. Each individual household is faced with an interest rate factor equai to

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1/ This approach captures the basic idea in Campbell and Mankiw (1989) who provide empirical estimates of the proportion of liquidity-constrained households in the seven major industrial countries. See also Japelli and Pagano (1989) who conducted a similar investigation based on data from Greece, Italy, Japan, Spain, Sweden, the United Kingdom and the United States.

$(1+r_{t+1})/\pi$. However, since insurance premiums and bequests cancel out, the effective interest factor on the aggregate level is just $(1+r_{t+1})$.

Aggregating individual households yields the following difference equation for private assets:

$$F_{t+1}=(1+r_{t+1})(F_t+W_tL_t-T_t-P_t^CC_t) \tag{24}$$

3. The government

The government collects lump-sum taxes, receives interest income on financial assets and purchases part of the economy's output for government consumption. 1/ Like the private sector, the government demands some combination of domestic and foreign goods. The difference equation for government debt is:

$$B_{t+1}=(1+r_{t+1})(B_t+P_t^GG_t-T_t) \tag{25}$$

where B_t is government debt, P_t^G is the price index of the composite government consumption good and G_t is real government consumption. The government faces an intertemporal budget constraint. The present value of government consumption must equal the present value of taxes and government debt. The level of taxation is adjusted gradually to yield a constant ratio between government assets and output. To ensure that the intertemporal budget constraint is satisfied, taxes are governed by the following rule:

$$T_t=(1-\tau)(\frac{T_{t-1}}{Y_{t-1}})Y_t+\tau(1-\frac{Y_{t+1}/Y_t}{1+r_{t+1}})B_t \tag{26}$$

4. Rest of the world

Under the standard small open economy assumptions, terms of trade are given. With endogenous terms of trade, export demand X_t^D is a function of domestic demand in the rest of the world X_t and relative output prices. Similarly to the consumption and investment demand functions, the export demand function can be written:

1/ Since this paper attempts to analyze the general effects of fiscal policy on aggregate demand rather than the effects of the tax structure as such, there is no need to provide for a complete specification in this regard. However, the model can be used to consider a range of taxes including consumption taxes, payroll taxes and income taxes applied to labor, capital and corporate income.

$$X_t^D = \gamma_1 (P_t^F / P_t^D)^{\gamma_2} X_t \tag{27}$$

5. National accounts

It may be helpful to restate some of the most important aspects of the model. Given input and output prices, interest rates and production technologies, firms determine the time paths for production, investment, wages and stock market values. Given dividends, wages and taxes, households determine the time paths for private consumption and private financial wealth. The government's decisions determine time paths for public consumption and public financial wealth. Consolidating the private and public sectors, it is straightforward to derive the accounts for the economy as a whole. The trade balance is simply the difference between output and domestic demand while the current account also includes interest payments on foreign debt. Net foreign assets are the difference between private net holdings of financial assets other than stocks and government net debt. National wealth is a particularly useful accounting concept in this model. Defined as the present value of output less investment expenditures plus net foreign assets, national wealth is the budget constraint for the entire economy:

$$\sum_{s=t}^{\infty} (1+r_t) \prod_{v=t}^{s} \left(\frac{1}{1+r_v}\right) [P_s^D Y_s - P_s^I I_s] + F_t - E_t + B_t$$
$$= \sum_{s=t}^{\infty} (1+r_t) \prod_{v=t}^{s} \left(\frac{1}{1+r_v}\right) [P_s^C C_s + P_s^G G_s] \tag{28}$$

A related concept is permanent consumption. Permanent consumption is the level of consumption which is consistent with national wealth growing in line with output. This makes total private and public consumption equal to a fraction $(1-(A_{t+1}/A_t)/(1+r_{t+1}))$ of national wealth.

6. Solution procedure

Models based on intertemporal optimization can generally not be solved analytically. The basic problem is that some endogenous variables (jumping variables) are conditioned on the entire future path of all variables in the model. Forward-looking variables in the present model include the shadow price of capital q, stock market values E, human wealth H and household financial wealth F. There is also a number of predetermined variables (state variables) which depend on the past history of the forward-looking variables. Such backward-looking variables include the capital stock K, government debt B and net foreign assets N. While the initial values of the backward-looking variables are known, all that can be done initially with respect to the forward-looking variables is to impose certain terminal conditions. This poses a problem usually referred to as a two-point boundary value problem.

In the present model, the main problem is to find the exact path for the capital stock and the shadow price of capital consistent with optimizing the firm's objective function. Once this problem has been solved, the rest of the model can be solved recursively. The solution to the firm's decision problem is characterized by saddle-point instability. Initially small deviations from the optimal path result in a sequence that eventually diverges away from steady state. It can be shown, however, that a certain path for the shadow price of capital results in an optimal path for the capital stock which gradually approaches steady state. This path can only be approximated through iteration. The extended path method by Fair and Taylor (1983) has proved to be very useful in this regard. This method has become increasingly popular as a tool for solving rational expectations models. The basic steps involved in solving the model can be described as follows. 1/

1. The first step is to calculate a steady state growth path solution which can be used to define terminal conditions for the forward-looking variables. Such a solution requires that all real variables grow at the same rate as the exogenous growth in productivity and that all relative prices are constant. Imposing these conditions yields a steady state value for the shadow price of capital $\bar{q}$. With endogenous terms of trade, the steady state price of capital must be determined simultaneously with the price of output. It is difficult to do this analytically. However, the model can be iterated to yield a combination of the two prices consistent with a steady state growth path.

2. The second step is to choose a terminal period T. The terminal period must be chosen so as to allow the model to be solved a sufficient number of periods beyond the actual simulation period. Guess an initial path $\{q_t^1\}_{t=0}^{T}$ and assume that $q_T=\bar{q}$. This yields a starting point for further iterations.

3. The third step is to solve the model in each period using the initial path and the starting values of all predetermined variables. With endogenous terms of trade, this includes finding the price which clears the market for the domestic good in each period. As already noted, this is by itself not an entirely straightforward exercise as it involves finding the market-clearing price through iteration.

1/ The model can be solved both with exogenous and endogenous terms of trade. The steps taken to solve the model are basically the same. However, with endogenous terms of trade, the price of the domestic good is determined by market-clearing. Generally, the market-clearing price can only be calculated through iteration. This makes the solution procedure somewhat more complicated and therefore more time-consuming than in the simple case with exogenous terms of trade.

4. The fourth step is to calculate a new path $\{q_t^{i+1}\}_{t=0}^T$ using the initial path to represent the expected next-period value of the shadow price of capital in each period. The new path replaces the old path and is subsequently used to represent expectations in the next iteration. Go back to the previous step and iterate until the difference between any two estimates for the same period of two consecutive iterations $\{q_t^{i+n}-q_t^{i+n-1}\}_{t=0}^T$ is sufficiently small to meet a convergence criterion.

5. The fifth step is to choose a new terminal period $T'>T$ and repeat the third and fourth steps until convergence is reached for the new extended simulation period. The solution period is extended until the difference between two consecutive solutions for the original solution period 0-T is small enough to meet a convergence criterion.

7. Empirical implementation

A typical weakness of many traditional macroeconomic simulation models is a lack of consistent forward-looking investment and saving decisions. Models based on intertemporal optimization seek to overcome this problem but are on the other hand more difficult to implement empirically the main reason being the assumption of rational expectations. With all variables except the backward-looking variables depending on the entire future path of all variables in the model, the solution of the model is conditional upon a particular set of assumptions about the future. In a planning context, this may be less problematic than it seems as assumptions about the future have to be made whatever the structure of the model. Nevertheless, the fact that expectations about the future determine the present makes simulations with intertemporal models both more complex and more time-consuming compared to conventional models. Solving the model given a path for all exogenous variables already requires a great number of iterations. Simulations involving a sequence of unanticipated shocks are obviously even more cumbersome as the entire solution procedure has to be repeated for each sub-period of the simulation period. This is achieved through moving the terminal period forward each time the solution procedure has to be repeated.

As for calibration, the simplest approach is to apply standard CGE techniques and impose values for parameters and variables which are able to reproduce empirical data for the base-period. 1/ This includes making a judgement about the initial deviation from steady state for a given set of current and future values of the exogenous variables. For the purpose of this paper, the model has been calibrated to match estimates for the

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1/ A more ambitious approach is to try to implement the model econometrically. Because of the particular specifications used in the model, the solutions to the firm's and household's maximization problems are the same under uncertainty as under certainty which make estimation of the key equations, the consumption and investment functions, possible. Econometric estimation would be a major step in developing the model further.

Norwegian non-oil economy in 1991 (see below box for key parameters). The procedure which has been applied is briefly as follows. All prices are initially normalized to unity and the capital stock is initially assumed to be in steady state. The share of capital in output and the depreciation rate are based on actual national accounts data. The share parameters of the CES composite good functions are determined on the share of imports in domestic demand in 1991. All remaining parameters are determined by assumptions. 1/ After having imposed starting values for output and employment, it is possible to solve for productivity and the capital stock. This yields values for investment and firms' stock market values. Given a starting value for net external assets and the market value of natural resources, in this case oil wealth, it is possible to calculate national wealth and permanent consumption. Given also a starting value for government assets, it is possible to derive starting values for private financial assets. Finally, for a certain path of taxes, it is possible to compute human wealth. Together with private financial assets, human wealth then determines private consumption.

1/ In addition, given the assumptions for the share of capital in output, the depreciation rate and the adjustment cost factor, it turned out to be difficult to match the actual starting value for investment. There are basically two ways to deal with this problem. One way is to adjust the parameters of the production and investment technologies. Another way, which was chosen in this paper, is to introduce a tax. Levied on gross profits net of depreciation, the tax serves to make investment in physical capital less attractive. The tax rate required for this purpose was equal to 20 percent.

Key Parameter Values

Parameter	Value	Definition
α	0.3	Share of capital in output
β	1.0	Investment adjustment cost factor
δ	0.035	Depreciation rate
ϵ_2	1.0	Elasticity of substitution between domestic and foreign goods in investment composite
π	1.0	Probability of survival
σ	1.0	Intertemporal rate of substitution
λ	0.25, 0.5, 0.75	Share of current income consumers
μ_2	1.0	Elasticity of substitution between domestic and foreign goods in consumption composite
γ_2	1.0	Price elasticity of foreign demand
τ	0.25, 0.5, 0.75	Rate of fiscal consolidation
A_{t+1}/A_t-1	0.02	Growth of productivity
r	0.04	Real interest rate

List of Parameters and Variables

Parameters

α	Share of capital in value added
β	Investment adjustment cost factor
δ	Depreciation rate
ϵ_1	Investment composite share parameter
ϵ_2	Investment composite substitution elasticity
π	Probability of survival
ρ	Rate of time preference
σ	Intertemporal rate of substitution
μ_1	Consumption composite share parameter
μ_2	Consumption composite substitution elasticity
λ	Share of current income consumers
τ	Rate of fiscal consolidation
γ_1	Export demand share parameter
γ_2	Export demand substitution elasticity

Variables

A	Productivity
B	Net government assets
C	Private consumption
C^D	Private consumption demand for domestic goods
C^F	Private consumption demand for foreign goods
D	Dividends
E	Market value of firms
F	Net foreign assets
G	Public consumption
G^D	Public consumption demand for domestic goods
G^F	Public consumption demand for foreign goods
H	Human wealth
I	Gross investment
I^D	Gross investment demand for domestic goods
I^F	Gross investment demand for foreign goods
J	Net investment
K	Capital stock
L	Employment
P^C	Price index of private consumption good
P^D	Price of domestic good
P^F	Price of foreign good
P^G	Price index of public consumption good
P^I	Price index of investment good
q	Tobin's q
R	Consumption propensity
r	Real interest rate
T	Government tax revenues
X	Foreign demand
X^D	Foreign demand for domestic goods

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