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FIVE ESSAYS ON FISCAL POLICY, INTERGENERATIONAL WELFARE AND PETROLEUM WEALTH

by

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A dissertation submitted for the degree of dr. oecon.

To my parents

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Bergen, December 1994

Øystein Thøgersen

CONTENTS

INTRODUCTION

Motivated by current macroeconomic problems facing the Norwegian economy, this thesis deals with fiscal policy and the management of petroleum wealth in a small open resource economy. We highlight the fact that considerable parts of the petroleum revenues are collected by the government and study in particular the interaction between fiscal policy, uncertain petroleum revenues and intergenerational welfare. The link between the issues analyzed in the various papers and the Norwegian economy is obvious. Still, most of the analyses apply equally well to other economies.

The first part of essay 1, "*Economic policy, macroeconomic performance and the Norwegian petroleum wealth - A survey*", discusses the calculation of the Norwegian petroleum wealth and takes a closer look at some wealth estimates. The magnitude of the petroleum wealth is considerable and amounts to approximately 117% of GDP in 1992 according to recent calculations. Revisons of the expected oil price path have led to large fluctuations in the wealth estimate. Since the government collects about 80% of the net cash flow from the petroleum sector, government wealth is highly exposed to oil price uncertainty. Hence, oil price fluctuations may influence fiscal policy, and the private sector is therefore exposed through fluctuations in the level of taxes, transfers and publicly provided goods.

This essay proceeds with a macroeconomic survey of the petroleum era in the Norwegian economy. Since the significance of the petroleum resources was recognized in the first part of the 1970s, the development of the petroleum sector and the spending of the petroleum revenues have contributed positively to national income. In the 1970s the international recession did not hit Norway. Based on expected future petroleum revenues, the government ran expansionary policies which included increased subsidies and other transfers, the implementation of new welfare benefits and tax cuts. In the 1980s the petroleum revenues increased due to higher oil prices and increased production, and the government accumulated financial assets. So far these assets have financed the budget deficits of the early 1990s.

The petroleum era has also been characterized by adjustment problems and business cycle fluctuations. The resource boom and the expansionary policies of the 1970s led to economic restraints at the end of the same decade, and the oil price plunge in 1986 triggered fiscal restraints which contributed to a stagnation in private demand for a long period of time. Correspondingly, private consumption has fluctuated rather widely since the beginning of the 1970s. Government consumption has increased steadily, however.

Beyond 2000, the petroleum sector is expected to be gradually phased out during a time span of several decades. We argue that the management of the remaining petroleum wealth in the next 10-15 years will determine whether the petroleum wealth will contribute to increased welfare for future generations. The outcome depends (at least) on (1.) the budget policy and the intergenerational allocation of the petroleum wealth, (2.) the impact of oil price uncertainty and the policies dealing with the risk exposure and (3.) the structural adjustment process. The following four essays attempt to shed more light on these issues.

Essay 2, "*Uncertain petroleum revenues, the government budget and precautionary saving*", studies the effect of uncertain government petroleum revenues on fiscal policy and the level of precautionary saving among the households. The analysis is based on a theoretical overlapping generations model where the uncertainty related to the government petroleum revenues is gradually revealed as the reserves are exhausted. The oil price risk is uninsured, and this implies that the petroleum production trajectory determines the risk exposure in different periods. Assuming that the government wants to stabilize its wealth, oil price shocks imply fiscal adjustments. If government expenditures are fixed, there is a negative relationship between a price shock and the tax level. The size of the tax adjustment is positively related to the size and the persistence of the oil price shock as well as the production level in the present period and the near future. Private households engage in precautionary saving since they face tax uncertainty. Depending on the production trajectory, the variance of the tax burden of different generations varies. Correspondingly, the level of precautionary saving varies too.

Turning to the analysis of expansionary fiscal policy, we consider a one period tax cut followed by tax increases in order to stabilize government wealth at a new and lower level. The effect depends on whether the tax cut is financed by intensified resource extraction in the following periods. This may lead to counterintuitive effects in the sense that intensified extraction triggers increased precautionary saving which (partly) offsets the wealth effect of the tax policy on the consumption of present generations. We believe that this analysis may contribute to the explanation of the rather modest effects of the expansionary fiscal policy in Norway after 1988.

Oil price uncertainty is also addressed in essay 3, "*International diversification and oil price risk*". This essay offers an empirical analysis of the impact of idiosyncratic oil price risk on consumption fluctuations in Norway, the Netherlands, Germany, France and Denmark during the period 1973-1988. As a point of departure we note that in a world economy characterized by high international capital mobility and complete markets, per capita consumption growth should be syncronized across countries. However, empirical evidence shows low consumption correlations between countries. Using a model framework which discriminates between the effects of non-insured risks and restrictions on international asset trade, we investigate whether non-insured idiosyncratic oil price risk contributes to the explanation of these findings.

The analysis focuses on the relationship between the consumption growth of the petroleum exporting countries Norway and the Netherlands, versus the consumption growth of the petroleum importing countries Germany, Denmark and France. Note that Denmark is defined as an petroleum importer since the significance of the Danish petroleum resources was not recognized during the time span considered. Generally, our empirical results support the view that non-insured idiosyncratic oil price risk accounts for parts of the observed low consumption correlations. This implies that both petroleum exporting and importing countries could benefit from innovations in the markets for claims to unextracted oil and gas.

By simulating an overlapping generations model calibrated to Norwegian data, essay 4, "*Petroleum wealth, debt policy and intergenerational welfare: The case of Norway*" (co-authored by Erling Steigum, Jr.), studies the intergenerational welfare effects of alternative strategies for spending the government petroleum revenues. Looking at the simulation model, there are 12 active generations in each period. The consumption path of the representative individual in each generation is determined by the maximization of a time separable utility function subject to a lifetime budget constraint. Assuming a "joy-of-giving" bequest motive, terminal wealth enters the utility function. The model captures the ageing of the population, and takes into account the effects of social security transfers. Both the real interest rate and the rate of labor-augmenting technical progress are exogenous.

We consider two scenarios. In the baseline scenario the government accumulates other assets to compensate for vanishing petroleum wealth (due to extraction), and no wealth consumption takes place. The wealth consumption scenario assumes that the government petroleum revenues are used to finance tax cuts, and no part of the petroleum wealth is transformed to other government assets. In order to stabilize government wealth at a lower level in the long run, taxes are raised to a level significantly higher than in the baseline scenario. The wealth consumption policy implies that the present generations of age 10 and older gain, while all very young and unborn generations loose. The underlying reason is that such a policy leads to a higher foreign debt, and future generations loose since the necessary trade surpluses crowd out consumption. Our simulations reveal a remarkable lack of symmetry between small consumption gains of the winners and large consumption losses of the young and unborn generations. Since the results are somewhat sensitive to the size of the gap between the real interest rate and the natural rate of growth, we present some sensitivity simulations. A larger gap implies a larger permanent consumption reduction.

Analyzing the effects of an unexpected drop in the government petroleum wealth, essay 5, "*Fiscal policy, structural adjustment and intergenerational welfare*", highlights how the structural adjustment process and the timing of the fiscal restraint influence intergenerational welfare. We propose a theoretical dependent economy model extended to incorporate both finite horizons of the individuals and structural adjustment costs in production. Consumer behaviour is modelled through the continous time Blanchard overlapping generations model where each agent independent of age faces a constant probability of death. The net income of an individual consists of a share of profit from private firms and labor income minus a lump-sum tax. There are two private production sectors, one producing traded goods (i.e. traditional manufacturing goods) and one producing non-traded goods. Labor is the only factor of production, and there are training costs involved in the process of transfering labor between sectors. This implies that an optimal structural adjustment process is gradual and time-consuming. The net petroleum export revenues are collected by the government. Assuming that no domestic labor is employed in the extraction activities, we focus exclusively on the "spending effects" of the petroleum sector.

Our analysis demonstrates that consumption, human wealth and the relative price of non-traded goods undershoot their new (and lower) stationary equilibrium values if the unexpected drop in the government petroleum wealth instantaneously leads to a tax increase which stabilizes government wealth. The present generations experience both the tax increase and the entire burden of the adjustment costs. Succeeding generations increase their human wealth and consumption since they face gradually less adjustment costs and at the same time benefit fully from the transfers of labor in earlier periods. If the tax increase is delayed, the undershooting tendency is weakened. The adjustment costs are distributed more evenly between the generations, but the long run stationary consumption level is lowered due to a higher tax burden.

ESSAY 1

ECONOMIC POLICY, MACROECONOMIC PERFORMANCE AND THE NORWEGIAN PETROLEUM WEALTH - A SURVEY*

ABSTRACT

This paper discusses the calculation of the Norwegian petroleum wealth and surveys economic effects of the development of the petroleum sector and the spending of the petroleum revenues. Emphasis is given to the relationship between the objectives of the government at different stages, the actual policy decisions and the macroeconomic performance. The petroleum era in the Norwegian economy has so far been characterized by high growth in the sheltered sector of the economy, growth in government spending and an increasing risk exposure to fluctuations in the petroleum revenues. The petroleum sector has contributed to a higher national income during the last two decades. At the same time many of the serious economic problems facing the Norwegian economy in the beginning of the 1990s, i.e. budget deficits, structural adjustment problems and vulnerability due to petroleum dependency, are closely linked to the petroleum sector and the spending of the petroleum revenues.

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1. INTRODUCTION

Since the extraction of the Norwegian petroleum resources started in 1971, the petroleum sector has grown rapidly, and it is now of vital importance to the Norwegian economy. In 1993 the petroleum sector contributed to 32.6% of total exports and 16.3% of GDP. In this survey we first discuss the calculation of the Norwegian petroleum wealth and look at some wealth estimates. Then we consider economic effects of the development of the petroleum sector and the spending of the petroleum revenues. We focus on the following four issues:

- The consumption of the petroleum revenues and intergenerational welfare.
- The intra-period allocation of government petroleum revenues between net transfers to private sector and government spending.
- The structural adjustment problems related to intersectoral transfers of labor and capital in response to fluctuations in both the petroleum revenues and the factor demand of the petroleum sector.
- The risk exposure of the society to uncertain petroleum revenues.

Obviously, there are other important issues including regional objectives, national control of the resources, business cycles and stabilization policy. This survey comments only briefly on these issues.

In the 1970s Norway could adjust to a higher consumption level as a consequence of the discovery of a large stock of petroleum resources and the existence of a significant petroleum rent. Both the spending of the petroleum revenues and the wage increases triggered by the phase-in of the petroleum sector in a period with low unemployment and full capacity utilization in the economy contributed to the consumption growth after the middle of the 1970s. The "resource boom" implied increased growth in the sheltered sectors of the economy, a real appreciation of the currency and a corresponding crowding out of sectors producing traditional tradeables. These structural changes meant a potential "re-entry" problem if the petroleum revenues should decline. Obviously, the re-entry problem is relevant when the extraction slows down and the date of exhaustion is near, but this problem may be even more troublesome if an unexpected drop in the petroleum price suddenly indicates that the chosen consumption level is not sustainable.

The oil price drop in 1986 and the corresponding rather dramatic worsening of the current account triggered contractionary economic policies towards reductions in private demand and a restructuring of the economy with the return to a more traditional industry based export sector. The experience after 1986 has revealed the significance of the re-entry problem, and today (1994) the structural adjustment problems are still a major challenge. In addition the intergenerational allocation of the petroleum revenues is intensively debated since the government in the beginning of the 1990s has run large budget deficits even though the government petroleum revenues have been considerable.

According to the 1993 annual report of the Norwegian petroleum directorate, the proven oil reserves amount to 20 years of production while the gas reserves amount to 115 years of production at the current rate. The gas production is expected to increase substantially, however. Hence, the expected petroleum revenues are considerable in the decades to come, and economic policy in the near future will to a large extent determine the impact of these revenues on intergenerational welfare.

The next section presents the petroleum wealth concept, surveys some wealth estimates and discusses the changes in the wealth estimates over time. Based on the four issues mentioned above, section 3 considers the political objectives which have been stated at different stages, the actual policy decisions and the macroeconomic performance during the petroleum era. A range of different poliy objectives (which we will return to) have motivated the policy decisions. We argue that the pursuit of these objectives contributed to the adjustment problems and the vulnerability to fluctuations in the petroleum revenues which Norway suffers from in the 1990s. Section 4 discusses the present challenges related to the spending of future petroleum revenues and the gradual decline of the petroleum sector. Section

5 concludes.

2. THE UNCERTAIN PETROLEUM WEALTH

We define the petroleum wealth as the market value of the Norwegian petroleum resources including existing oil rigs and other capital installations.[1] There are no efficient markets for petroleum fields and therefore no market prices which could facilitate the calculation of the petroleum wealth.[2] The petroleum wealth is therefore calculated as the present value of the expected net cash flow from the petroleum sector, see the calculations presented by the Central Bureau of Statistics of Norway (in for example "Økonomisk utsyn over året 1989" and "Økonomisk utsyn over året 1990") and the Norwegian Ministry of Finance (in for example the Revised National Budget for 1992, "Stortingsmelding nr. 2 (1991-92)" and the Long Term Program 1994-97, "Stortingsmelding nr. 4 (1992-93)").

2.1. The simple principles of calculation

The net expected cash flow from the petroleum sector is calculated by using expected values for future oil prices, field specific gas prices, fixed production trajectories and costs. If time is discrete and there are n petroleum fields, the period t expected net cash flow in period s is given by

[1] The petroleum wealth can be split into one "pure" resource wealth component and one real capital component. In some papers and reports the petroleum wealth term refers to the former component only. The pure resource wealth is calculated as the net present value of the petroleum *rents*, see for example the government Long Term Program 1994-1997 ("Stortingsmelding nr. 4 (1992-93)").

[2] Possible explanations to the seemingly lack of any market for petroleum fields include risks of nationalization, public regulation and taxation of the resources, see Lund (1987). However, no real attempt to sell claims to petroleum fields (or shares in fields) has ever been reported by Norwegian authorities. Hence, the possibility of selling away claims to unextracted petroleum in the North Sea should not be excluded.

$$E_t(\pi_s) = E_t\left(\sum_{i=1}^{n}(p_s x_{s,i} + q_{s,i}y_{s,i} - c_{s,i})\right). \tag{1}$$

Here p_s is the oil price, $x_{s,i}$ is the oil production, $q_{s,i}$ is the gas price, $y_{s,i}$ is the gas production, $c_{s,i}$ is the costs and investments and E_t denotes the expectation conditional on information available in the beginning of period t. In period t the petroleum wealth is given by

$$PW_t = \sum_{s=t}^{T}\frac{E_t(\pi_s)}{(1+r)^{s-t}}, \tag{2}$$

where T is the period of exhaustion and r is a constant real discount rate. In most petroleum wealth calculations the expected production trajectories, $x_{s,i}$ and $y_{s,i}$, are adopted from forecasts made by the Norwegian Ministry of Industry and Energy or other institutions. It is an open question whether these trajectories are optimal in the sense that they maximize the petroleum wealth.

Obviously, the estimates of the petroleum wealth are very rough. To a great extent this is a consequence of the uncertainty associated with long term projections of both the petroleum prices as well as the other variables on the RHS of (1). Additionally, there are some crucial methodological issues related to the calculations based on (1) and (2). A shortcoming is the neglect of the possibility of choosing flexible extraction strategies, i.e. the option to make future production levels (and in particular the timing of when to start the development of new petroleum fields) contingent on the contemporaneous information regarding prices and other variables, see for example Brekke et al. (1988). Calculations in Brekke et al. suggest that the value of permitting flexible strategies could be substantial, and the possible significance of flexible strategies is also recognized in several government reports dealing with the petroleum sector (see for example section 5.4.3 in NOU 1988:21). However, to the knowledge of this author, no published estimates have yet taken flexible extraction strategies into account, and it is possible to argue that the assumption of a fixed extraction strategy is a tractable and satisfactory first approximation.[3] Firstly, the presence of considerable adjustment costs related to major adjustments in the production level or temporary halts in the production from a field indicates that it is rarely optimal to change the production level in response to price fluctuations (Aslaksen et al. (1990)). Secondly, the decisions regarding when to start the development of a petroleum field seem to be determined by political considerations at a rather early stage, and it is hard to imagine that these considerations reflect the government's attempt solely to maximize the value of the petroleum wealth. Thus, the potential value of permitting flexible strategies may be hard to realize.

Another problem is related to the choice of the appropriate discount rate. Efficient wealth management under certainty implies that the marginal rate of return on all types of assets should be equalized, which means that the appropriate discount rate in the petroleum wealth calculations is given by the marginal rate of return on other assets (Aarrestad (1978, 1979), Hoel (1981)). Based on calculations by notably Kartevoll et al. (1980) which indicate that the average return on capital in Norway has been 7%, the standard assumption used by the Central Bureau of Statistics of Norway and the Norwegian Ministry of Finance is to apply a 7% rate (which is the "official" social discount rate for public projects). This choice is open to criticism. For example Hoel (1981) argues that present and future marginal returns on other types of Norwegian assets will probably be lower than 7%, and he uses a 4% discount rate in his petroleum wealth calculations. Considering Norway as a small open economy, we may also suggest the use of the return on foreign financial assets as the relevant discount rate, and a reasonable estimate of this return is probably smaller than 7%.

A fundamental issue in the derivation of the discount rate for petroleum wealth calculations is uncertainty. The sensitivity of national income and other macroeconomic target variables to fluctuations in the net cash flow from the petroleum

[3] Brekke et al. (1988) calculate the value of a single petroleum field (the "Snorre" field) only.

sector calls for a risk adjusted discount rate.[4] Lund (1990) argues that the 7% estimate of Kartevoll et al. includes the realizations of risk premia. Hence, a 7% discount rate may be interpreted as a risk adjusted rate, but it is still not clear whether this risk adjustment is appropriate for petroleum wealth calculations. It turns out that both the 7% discount rate used in most petroleum wealth calculations as well as alternative discount rates picked in an ad-hoc manner must be regarded as crude approximations. Since the horizon of the petroleum wealth calculations is rather long, it also follows that the wealth estimate is very sensitive to the choice of the discount rate. The volatility of the 1989 petroleum wealth estimate of the Central Bureau of Statistics (see section 2.2) has been calculated to 14.2% by Thøgersen (1990: p. 58)).

2.2. Estimates of the petroleum wealth

The Central Bureau of Statistics of Norway has calculated the petroleum wealth in each year from 1973 to 1991.[5] These wealth estimates are illustrated in figure 1, and they can be compared to a new estimate presented in the government Long Term Program 1994-97 ("Stortingsmelding nr. 4 (1992-93)"). This new estimate amounts to 820 billions NOK. The large fluctuations in the estimates are striking, and in order to study the changes in the petroleum wealth closer, we decompose the change in the petroleum wealth between two succeeding periods (*t* and *t+1*) in

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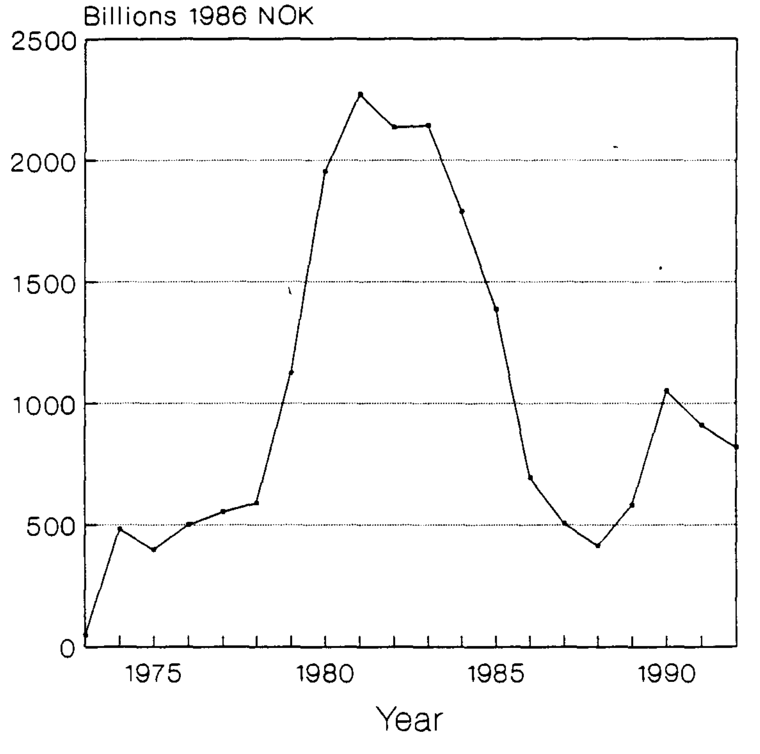
4 Within the context of a single marginal petroleum field, the derivation of a risk adjusted discount rate is discussed by Lund (1987, 1990). Some topics related to the derivation of a relevant discount rate for petroleum wealth calculations are discussed by Stensland and Sunnevåg (1990). A conclusion which is stressed in this literature, is that the discount rate should vary over time and between different components of the net cash flow (since the risk characteristics may vary). This is not yet reflected in any empirical petroleum wealth calculation, however.

5 These calculations and the data are documented in for example Brekke et al. (1989) and Aslaksen et al. (1990).

Figure 1 **Estimates of the Norwegian petroleum wealth 1973-1991**
Source: Central Bureau of Statistics of Norway, "Økonomisk Utsyn over året 1989" and "Økonomisk utsyn over året 1990".



three parts.[6] Using (2), we obtain

$$(3) \qquad PW_{t+1} - PW_t = -\pi_t + r\left(\sum_{s=t+1}^{T} \frac{E_t(\pi_s)}{(1+r)^{s-t}}\right) + \sum_{s=t+1}^{T} \frac{[E_{t+1}(\pi_s)-E_t(\pi_s)]}{(1+r)^{s-t-1}}.$$

The first term on the RHS shows that the net cash flow from the extraction in period t contributes to a reduction in PW_{t+1}. The second term is the positive effect of less heavy discounting of future net cash flows, and this term is given by the return on the remaining petroleum wealth after the extraction in period t has taken place. The last term is the effect of changes in the expected future net cash flow due to new information in period $t+1$ regarding prices or other variables.

The Central Bureau of Statistics of Norway has calculated the three different components of the changes in the petroleum wealth estimates for 1973-1989, and the results are reproduced in table 1. It follows from this table that the large fluctuations are mainly caused by changes in the expected future net cash flow. In for instance 1979 and 1985, changes in the expectations amounted to more than 700 billions NOK, and during the whole period the average absolute adjustment caused by changes in the expectations alone is 287 billions. The other two components of the changes in the petroleum wealth are much smaller, but still it is interesting to note the significant fluctuations in each of them over time.

The considerable changes in expectations are primarily due to the fact that major revisions in the expected oil price path have taken place in response to oil price shocks (i.e. many oil price shocks have been interpreted as persistent). The expected price paths used in the calculations are adapted from various government reports, and as illustrated by Aslaksen et al. (1990), the typical expected price path

[6] The very high petroleum wealth estimates in the beginning of the 1980s were not very optimistic compared to alternative wealth estimates presented by other authors at the same time. Using a lower discount rate and favourable price assumptions, Bjerkholt (1981) calculated a petroleum wealth estimate equal to 3915 billions, while the average estimate found in Hoel (1981) is approximately equal to 3500 billions (his highest estimate exceeds 7000 billions).

for a given year is characterized by a positive and constant growth rate regardless of the initial price level which is given by the actual price at the time. Rather small oil price fluctuations may therefore trigger major changes in the expected future net cash flow which in turn imply large changes in the wealth estimate. This means that price uncertainty is the most important source of uncertainty in the estimation of the petroleum wealth.

Year	Petroleum Wealth	Changes in Expectations	Expected return on remaining wealth	Net Cash flow
1973	47	428	4	-4
1974	482	-130	35	-12
1975	398	60	29	-12
1976	499	13	35	-7
1977	554	-6	38	-3
1978	590	504	41	10
1979	1125	777	77	24
1980	1955	239	133	55
1981	2273	-233	155	59
1982	2136	-88	146	51
1983	2143	-441	146	59
1984	1789	-460	121	62
1985	1388	-731	93	56
1986	694	-219	47	16
1987	506	-106	34	21
1988	413	162	27	20
1989	582	-	39	29

Table 1 Estimates of the Norwegian petroleum wealth and the three different components of the changes in the estimates. Source: Central Bureau of Statistics of Norway, "Økonomisk utsyn over året 1989".

The changes in expectations are also influenced by new information about the reserve level. The resource stock has occasionally been upgraded due to the discovery of new fields or due to technological progress enabling increased exploitation of the resources in the existing fields. In addition, information from geological studies of the Norwegian continental shelf has implied an increase in the estimate of reserves expected to be discovered in the future.[7] However,

[7] The annual reports of the Norwegian Petroleum Directorate present updated estimates of reserves in both discovered fields and fields expected to be discovered in the future.

changes in petroleum wealth estimates caused by revisions of the resource stock assumptions are of minor significance compared to changes caused by adjustments in the price path.

It follows from equation (3) that the sign of the period t *expected* change in the petroleum wealth is undetermined since, by definition, $E_t[E_{t+1}(\pi_s)-E_t(\pi_s)]=0$ for all s. The petroleum wealth is expected to be kept constant if π_t is equal to the expected return on the remaining wealth. Obviously a lower π_t means $E_t[PW_{t+1}-PW_t]>0$, while a higher π_t means $E_t[PW_{t+1}-PW_t]<0$. If the petroleum wealth should contribute to increased welfare for all future generations, the expected sustainability of a constant level of "petroleum consumption" calls for financial lending (i.e. accumulation of a petroleum fund) in the latter case. In the case of $E_t[PW_{t+1}-PW_t]>0$, this consumption strategy implies financial borrowing. Hence, positive petroleum production does not necessarily mean a decumulation of the petroleum wealth. Naturally, the presence of uncertainty implies that a consumption level expected to be sustainable ex-ante, may be deemed as over-consumption ex-post.

Discussing the consumption of the petroleum wealth, we also note that the consumption decisions can be separated from the production decisions provided that two assumptions are satisfied. Firstly, we must assume that there are no interdependencies between production and consumption. Secondly, we must either disregard uncertainty or assume that the uncertainty is perfectly correlated with the return from a portfolio of marketable assets (see Aslaksen et al. (1990), Brekke (1990)). Given these assumptions, optimal wealth management implies that the production trajectories ($x_{s,i}$ and $y_{s,i}$) are chosen in order to maximize the petroleum wealth, while the optimal consumption path is derived separately for a given (maximal) value of this wealth.

Directly, through the public petroleum company Statoil and public participation in the development of several fields, or indirectly through taxation, more than 80% of the net Norwegian petroleum revenues are collected by the government, see for example the Revised National Budget for 1990 ("Stortingsmelding nr. 2 (1989-90)").

The Norwegian government is therefore strongly exposed to the uncertainty in the petroleum revenues, and fluctuations in these revenues have an immediate impact on the size of the government budget deficit (or surplus). It follows that the exposure of the private sector to uncertain petroleum revenues is in part related to potential adjustments in the tax level and the level of government spending, and in part to fluctuations in the factor demand of the petroleum sector.

3. PETROLEUM WEALTH AND MACROECONOMIC PERFORMANCE[8]

Recalling the four major issues mentioned in the introduction, we turn to our survey of the objectives of the government at different stages, the actual policy decisions and the macroeconomic performance.

3.1. The 1970s - Expansionary policies in a wealthier nation

Norway entered the 1970s after two decades of high and steady economic growth. When the significance of the petroleum wealth was recognized, it triggered optimism and high policy ambitions. A range of objectives was presented in the first government report dealing with the petroleum sector and the economy in a broad sense ("Stortingsmelding nr. 25 (1973-74)"). The basic idea was to spend the petroleum revenues in order to create "a qualitatively better society", involving increased government spending on social security, culture, education and infrastructure as well as an expansion of government activities towards the maintenance and development of rural areas. It was also pointed out that the petroleum revenues should finance considerable tax cuts and that the length of the working day should be reduced. In addition, it was emphasized that the responsibility for the rest of the world implied that Norway should increase its development aid to Third World countries. Hence, the list of policy objectives was extensive, and it was repeatedly highlighted by the Labor Party government in office during the middle of the 1970s, see for example Kleppe (1976).

[8] Other surveys focusing on various topics related to the petroleum sector and the spending of the petroleum revenues include Strøm (1976), Skånland (1988, 1992), Steigum (1991) and Brekke et al. (1992).

"Stortingsmelding nr. 25" contained more than promises. Especially, it offered a careful discussion of the potential structural adjustment problems associated with the phase-in of the petroleum sector. In fact this was adressed as the most important issue in the development of the petroleum sector. In the actual situation characterized by very low unemployment and full capacity utilization, the need for intersectoral transfers of labor and capital from the sectors producing traditional tradeables to the petroleum sector and the sheltered sectors of the economy was recognized. A major concern was how to avoid de-industrialization of local communities in rural areas.

In order to facilitate the structural adjustment process, the report strongly recommended a high degree of governement intervention in the restructuring of industries and a moderate rate of extraction. As an example, an extraction level which gradually approached 90 million tons oil equivalent (t.o.e.) per year in the beginning of the 1980s and then was kept constant at this level, was considered a relevant "intermediate" alternative. Statoil, the government petroleum company, should serve as a main policy instrument in the management of the petroleum sector (see Johnsen (1976)). The report also proposed a level of "petroleum consumption" (i.e. petroleum revenues allocated to consumption) increasing from 150 millions NOK in 1975 to 6 billions NOK in 1980 (amounts in 1974 NOK).[9] Thus, in contrast to the long list of promises stated above, the focus on gradual increases in exploration and consumption signaled a rather high degree of prudence in the economic policy.

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[9] The significance of the potential adjustment problems following the proposed extraction- and consumption paths was intensively debated during the 1970s and the beginning of the 1980s, see for example Norman (1975, 1980), Kleppe (1976), Schreiner (1976), Bjerkholt et al. (1980) and Espeli (1992). The mainland industry lobby wanted a lower level of petroleum consumption in order to limit the level of structural adjustments and thereby protect the industries producing traditional tradeables. This view was not shared by the government and many economists who pointed at the fact that a real appreciation and structural adjustments must take place in the process leading to increased welfare by realizing for example the ideas of "a qualitatively better society".

The intergenerational allocation of the petroleum wealth was briefly mentioned in "Stortingsmelding nr. 25". It was emphasized that the concern for future generations called for an allocation of parts of the petroleum revenues to investments including financial investments abroad. Still, no explicit consumption strategy involving any sort of rules for the accumulation of a petroleum fund was discussed. Kleppe (1976) and Øien (1976) questioned the desirability of a high degree of foreign financial investments. They argued that the fears of political instability and hyperinflation implied that the return on foreign financial assets was more risky than the the return on the petroleum wealth (which essentially is given by the oil price). Since the level of real capital investments was already high in Norway, they recommended a moderate rate of extraction as the appropriate response to the demand for long run considerations in the management of the petroleum wealth.

The arguments of Kleppe and Øien must be interpreted in the light of a limited international trade in financial assets at the time. Today, the international capital market has developed, and it is hard to accept their arguments against foreign financial investments. After two decades of volatile petroleum prices and a corresponding uncertainty in the petroleum wealth estimate, the risk related to petroleum price shocks is obvious. It is probably fair to say that this risk was not recognized in the middle of the 1970s, and potential problems related to the risk exposure of the society were not addressed in "Stortingsmelding nr. 25".

Looking at the actual policy decisions in the period 1973-1977, it turns out that the implementation of the promises related to the idea of "a qualitatively better society" was given high priority. In 1976 the length of the working-week was reduced from 42.5 to 40 hours, and in 1977 an extensive working-environment law establishing improved standards of the working conditions for all types of workers was passed. The period was characterized by active stabilization and income policies. In order to protect industries facing profitability problems as a consequence of the international recession following the oil price shock in 1973-1974, the government transferred huge subsidies to selected industries, notably shipbuilding yards and textile industries. These subsidies prevented lay-offs in industries located in central as well as rural areas. The long run consequences were, however, open to criticism. As described in detail by Espeli (1992), this policy gave rise to intense lobbying from labor unions and the Federations of Norwegian Industries. Hence, the subsidies were maintained for a long period of time and structural adjustments counteracted. Considerable resources were allocated to unprofitable industries which could not be sustained in the long run (Strøm (1991)).[10]

The income policy in 1976 and 1977 involved direct government participation in the wage negotiations. In order to combine a lower growth in nominal wages with a significant growth in real disposable income, the government agreed to cut taxes. This policy was motivated by an explicit objective of the government to increase the income of industrial workers, and it ensured that the high income growth following the sharp wage increases in 1974 and 1975 continued. At the same time the income level in the agricultural sector increased significantly. This was due to a government resolution in 1975 which stated that the net income level should be equalized between the industry and agricultural sectors. Therefore favourable wage increases in the industry sector triggered corresponding increases in the government transfers to the farmers.

Turning to the macroeconomic performance in the period 1973-1977, we first note that economic growth stagnated in OECD-Europe after the oil price shock in 1973, while a petroleum based growth continued in Norway (see figure 2). The joint effect of increased factor demand from the petroleum sector in development and the expansionary income- and stabilization policies boosted aggregated demand. The investment level in the petroleum sector was high, and both private and government consumption increased sharply until 1977 (figure 3).

The dramatic worsening of the competitiveness of the (exposed) Norwegian

[10] A theoretical analysis of the effects of lobbying in an industrialized society is given by Baldwin (1993). In his terms the government, due to the incentives involved, "picks the losers since they lobby harder".

Figure 2 **GDP growth in Norway, Mainland Norway and OECD-Europe 1973-1992, 1973=100.**
Sources: Steigum (1993) and NOU 1992:26.

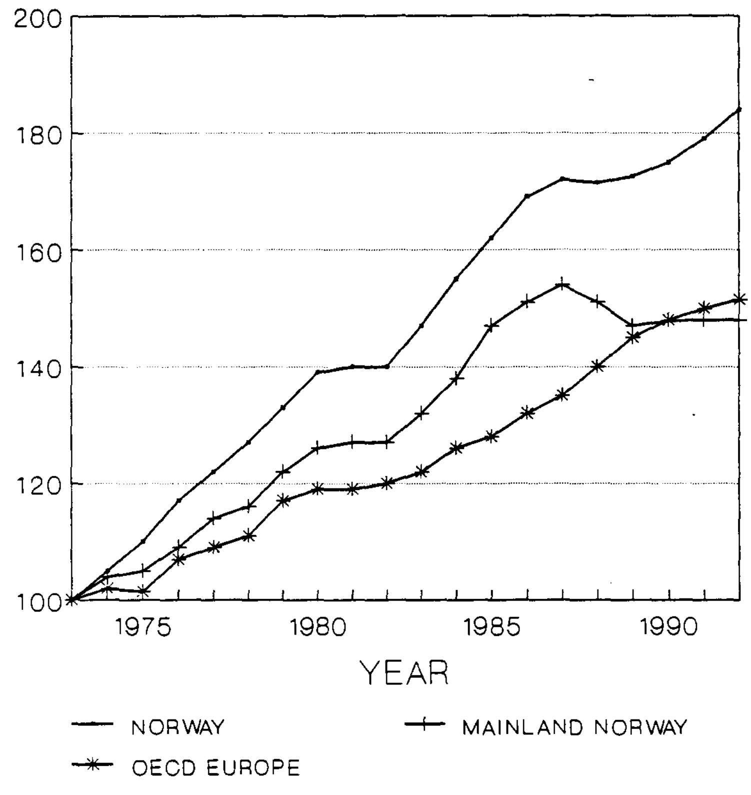
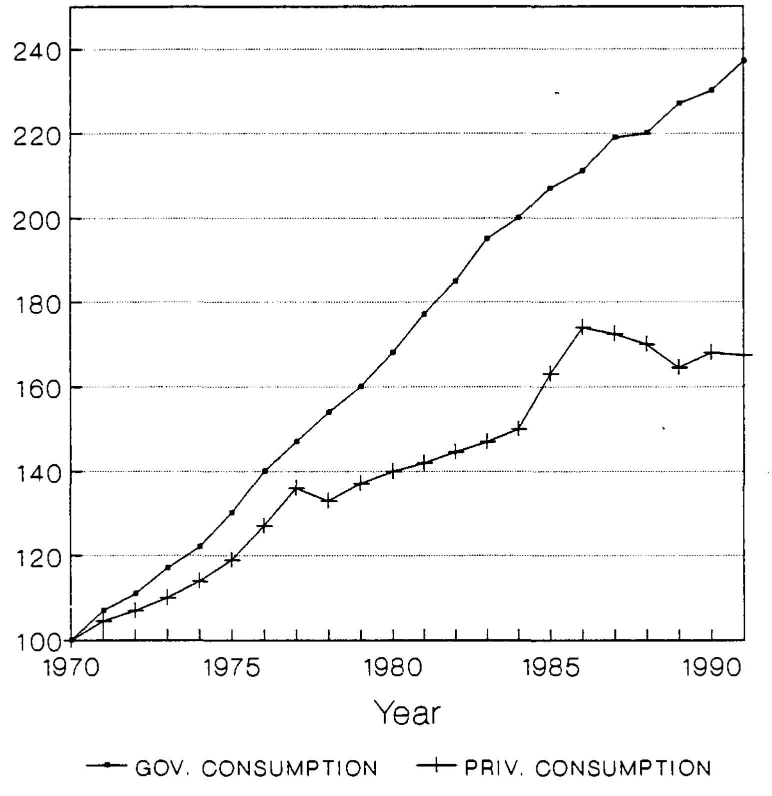


Figure 3 **Private and government consumption growth 1970-1991, 1970=100**
Sources: NOU 1992:26 and Central Bureau of Statistics of Norway.



manufacturing industries is striking. Figure 4 illustrates the time path for relative unit labor costs. Wage increases, a productivity slow down and an appreciation of the Norwegian currency all contributed to a sharp increase in this indicator during the period 1970-1977. Corresponding to the real appreciation, the expansion of the sheltered sectors and the petroleum sector crowded out firms producing traditional tradeables (see table 2).

	1970	1975	1980	1985	1989	1991
	Employment per sector					
Sheltered sectors	76.8%	78.3%	79.2%	81.8%	83.8%	83.7%
Exposed sectors						
Import competing	15.9%	15.5%	14.9%	12.8%	10.7%	10.4%
Export	7.3%	6.0%	5.4%	4.5%	4.5%	4.9%
Petroleum	0.0%	0.2%	0.5%	0.9%	1.0%	1.0%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Memo.: Manufacturing	24.5%	24.3%	21.8%	18.8%	15.8%	15.5%
	Contribution to GDP per sector					
Sheltered sectors	72.7%	73.7%	66.1%	66.8%	73.0%	71.5%
Exposed sectors						
Import competing	14.3%	13.8%	11.1%	8.7%	8.0%	7.8%
Export	13.0%	9.6%	7.7%	6.0%	6.8%	6.2%
Petroleum	0.0%	2.9%	15.1%	18.5%	12.2%	14.5%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Memo.: Manufacturing	21.8%	21.7%	15.6%	14.0%	15.0%	13.7%

Table 2 Structural adjustments 1970-1989.
Source: Steigum (1991), Central Bureau of Statistics of Norway

Figure 5 illustrates the serious worsening of the current account and the level of foreign financial assets during 1971-1977. This was caused by increased net imports triggered by growth in aggregated demand, loss of competitiveness in both the import competing and the export industry and in addition increasing financial costs related to the accumulation of foreign debt. Naturally, an underlying reason for these effects was the expansionary policies and the corresponding budget deficits in this period (see figure 6). To a large extent this development reflected an

Figure 4 **Relative unit labor costs (RULC) and relative productivity (RP) in manufacturing 1970-1992, 1970=100.**
Source: The National Budget for 1994.

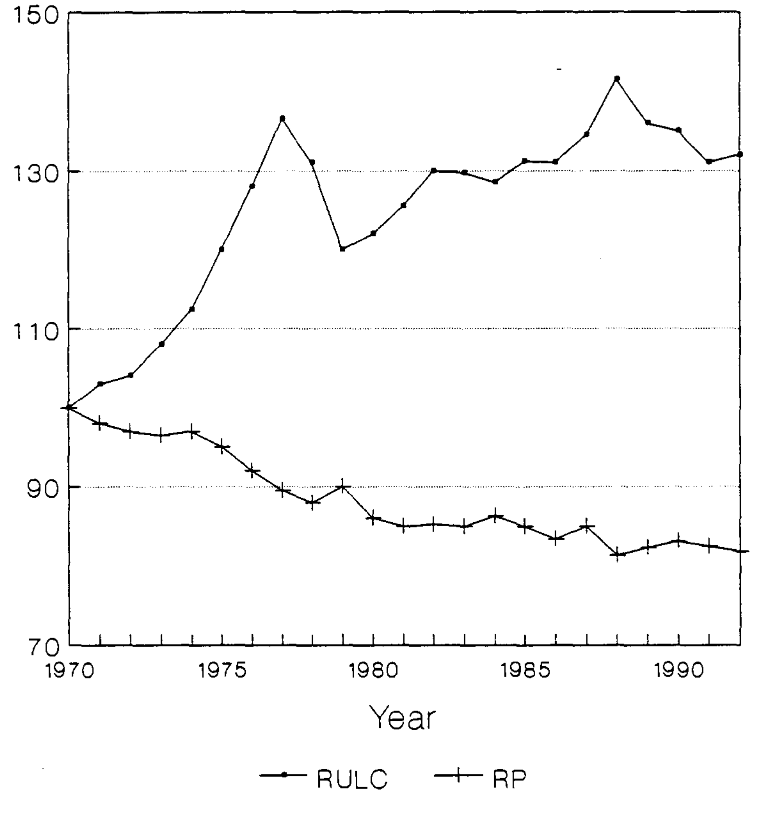


Figure 5 **Current account and net foreign assets 1970-1992**
Source: The National Budget for 1994.

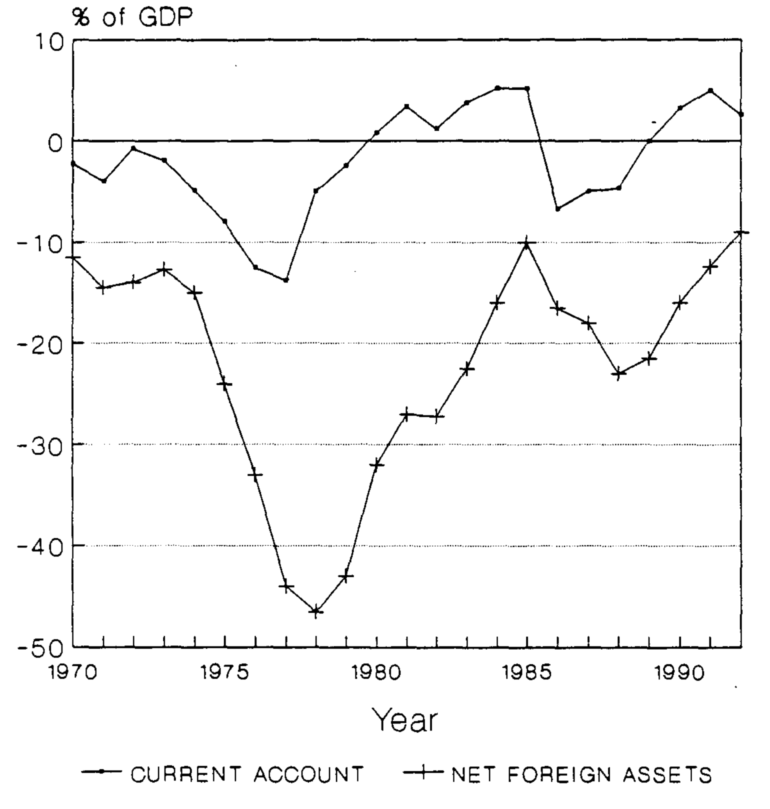
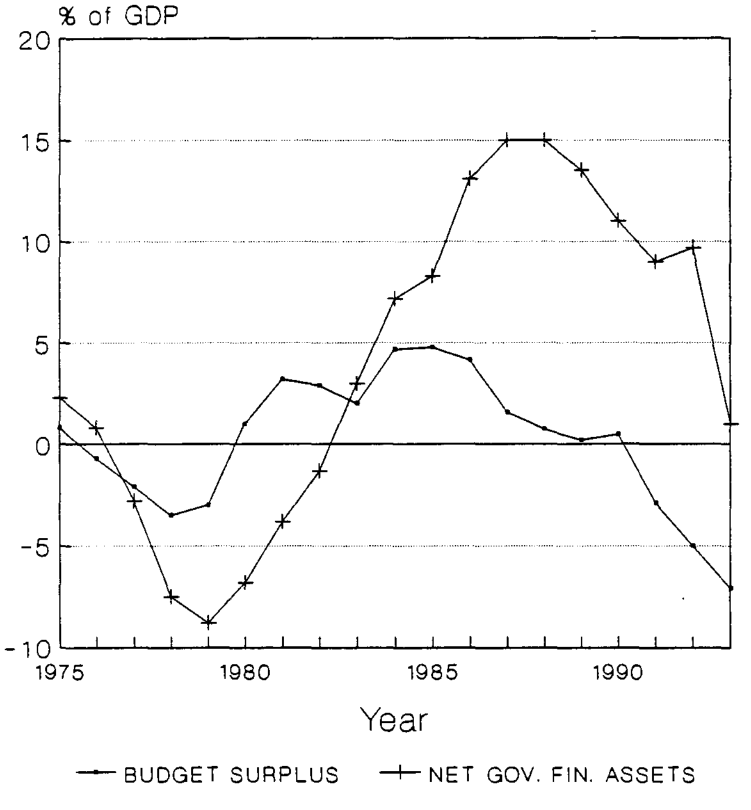


Figure 6 **Central government budget surplus and net financial assets 1975-1993. Without capitalisation of direct investments in state enterprises.**
Sources: The National Budget for 1991 and for 1994.



economic policy based on the spending of expected revenues from *future* petroleum extraction. As a consequence, the international recession did not hit Norway, and in contrast to the rest OECD-Europe, the unemployment rate was kept low. On the other hand, in 1977 the current account deficit was 14% of GDP and the foreign debt exceeded 46% of GDP. Comparing the macroeconomic performance and the objectives presented in "Stortingsmelding nr. 25", we may conclude that the pursuing of the promises related to "a qualitatively better society" dominated, fueled by the lobbying of pressure groups associated with various sectors of the economy and representing both capital owners and labor (see Seip (1981)). Less attention was given to the careful recommendations regarding moderate increases in consumption.

The period 1978-1981 was characterized by policies aiming at a reduction of the high growth rates for prices and production costs. A devaluation was carried out in February 1978, and a price and wage freeze was implemented in the fall of the same year. The supply of credit was constrained through reduced lending from the public financial institutions (i.e. the "state-banks") and a stricter regulation of the level of lending from private banks. Later, a new price freeze was introduced before the election in 1981. In addition, attempts were made to reduce the high level of subsidies to targeted industries. This was difficult due to intense lobbying from the industries, and subsidies once meant to be transitory were to a large extent maintained, see Espeli (1992). The expansion of the welfare state continued too, and in 1978 a very generous sick pay act was passed.

It is also interesting to note the discussions around a proposed agreement between the Norwegian government and the Swedish car manufacturer Volvo in 1979 (see Espeli (1992)). Among other things, this agreement was planned to involve a swap of shares in Volvo in exchange for participation in the development of petroleum fields in the North Sea. This swap could be interpreted as an interesting attempt to diversify the petroleum related risks in the Norwegian national portfolio (although this interpretation was not highlighted in the negotiations). The proposed agreement was, however, rejected by the Volvo shareholders.

The combined effect of the restraint in economic policy and a positive and increasing net cash flow from the petroleum sector (see table 1) turned the economic development. As shown in figure 4, the relative unit labor costs dropped for a while, resulting in transitory decreases in imports and improvements of market shares of the sectors producing tradeables. Figure 5 and 6 illustrate the turning points in 1977-1988 for the current account and the government budget deficit/surplus. Looking at figure 3, it follows that the restrictive economic policies implied a stagnation in private consumption. Financed by increasing government petroleum revenues, the strong growth in government consumption continued.

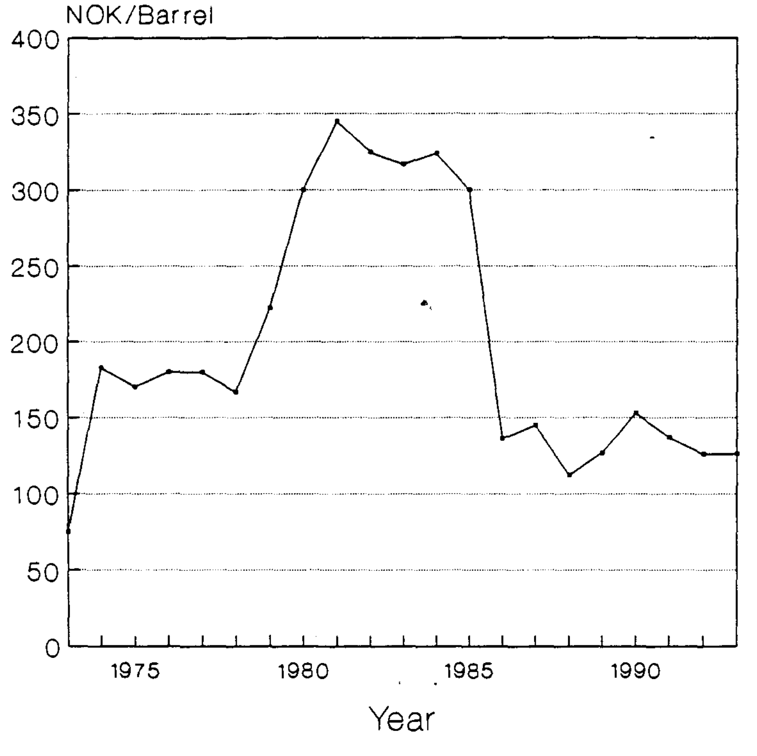
3.2. The 1980s - Increasing petroleum revenues and optimism

As the oil price increased in the beginning of the 1980s (figure 7), the need for restrictive economic policies vanished. The emphasis on the choice of the level of extraction was gradually weakened, while the intra- and intertemporal allocation of the petroleum revenues received more attention.[11] In addition many authors addressed the potential problems related to increasing exposure to oil price shocks, see Norman (1980), Thonstad (1981) and Øien (1982). The next government report dealing with the petroleum sector and the Norwegian economy, NOU 1983:27 ("Tempoutvalgets innstilling"), reflected these changes in the priorities.

This report feared structural adjustment problems in the mainland economy caused by fluctuations in the spending of the government petroleum revenues and in the factor demand of the petroleum sector. Hence, it highlighted the importance of smooth and predictable levels of both investments in the development of new fields and the spending of the revenues. The report recommended the government to accumulate assets in the international capital market, i.e. a petroleum fund. This would contribute to a separation of extraction from spending. After the period of

[11] An extraction level gradually approaching 90 millions t.o.e. per year was presented as an example in "Stortingsmelding 25 (1973-74)", but was in fact adopted as a main objective during the last part of the 1970s and the beginning of the 1980s, see for example the government Long Term Program 1982-1985 ("Stortingsmelding nr. 79 (1980-81)").

Figure 7 **Crude oil prices 1973-1993**
Source: The National Budget for 1994.



exhaustion the return from this fund should enable future generations to benefit from the petroleum resources as well. Since the report recognized that the oil price was more volatile than previously thought, the petroleum fund should also serve as a buffer against short run fluctuations in the net cash flow from the petroleum sector.

The report discussed the implementation of a petroleum fund in some detail. Two concerns should be mentioned. Firstly, financial assets should be accumulated in the international capital market. Real domestic investments were not considered relevant due to doubts about the significance of the return (the investment level was already high in Norway) and problems related to whether the government was able to collect the return efficiently. The management of the fund should be based on commercial guidelines regarding expected return, risk and liquidity. As an example, which must be interpreted in the light of the contemporaneous estimate of the petroleum wealth (see figure 1), the accumulation of a fund amounting to 1000 billions NOK was considered as realistic. Secondly, the report signaled a limited confidence in the potential of economic policy and questioned the ability of the politicians to give priority to the accumulation of a large fund instead of spending the revenues in the short run. It pointed out that the implementation of a petroleum fund with approved formal rules for the allocation of the petroleum revenues, could, in a weak sense, commit the government to give priority to long run considerations.[12]

As a consequence of the high oil prices during the early 1980s, the government received large petroleum revenues. These revenues were allocated between government consumption which continued to grow quickly (figure 3), and government saving. No formal petroleum fund was implemented despite the clear

[12] A credibility problem would still exist since formal rules approved at an early stage could be altered by the Parliament later on. An interesting possibility would be to incorporate these rules in the Constitution. Since it takes a 3/4 majority to change the Constitution, this could to some extent limit the credibility problem, see Carlsen (1992) for a theoretical analysis.

recommendation in NOU 1983:27. Still, the central government ran budget surpluses (figure 6) and accumulated financial assets which exceeded 13% of GDP in 1986.

The direct expansionary effects of the high government petroleum revenues on private sector were of minor significance during the first part of the 1980s (see Skånland (1988)). As indicated in figure 3 the growth rate of private consumption was rather low during 1980-1984. However, in 1985 the behaviour of private sector changed dramatically in response to the deregulation of the Norwegian credit market. A sharp increase in the supply of credit, the maintenance of a low politically fixed nominal interest rate and a high degree of deductibility of interest payments gave rise to debt financed private investments and a consumption boom in 1985 and 1986.[13] Looking at figure 3, the steep increase in the growth rate of private consumption is apparent. Private consumption as a percentage of GDP increased to 54% in 1986. We note that this was rather low compared to the OECD average of 62%.[14] The private dissaving influenced the current account negatively, but this effect was to a large extent masked by high petroleum revenues and corresponding government budget surpluses. As indicated in figure 5, the current account was positive during 1980-1985.

The petroleum dependency increased during the first part of the 1980s. The government spending of petroleum revenues increased, and the gain in relative unit labor costs obtained in the late 1970s disappeared (figure 4). Hence, the expansion of the sheltered sectors of the economy and the crowding out of industries producing traditional tradeables continued (table 2). The sensitivity of national income and exports to oil price fluctuations increased, but still no strategy dealing with oil price uncertainty was presented. Norman (1980) discussed the possibility of using international stock markets in order to diversify the national

[13] For surveys of the financial deregulation and the credit boom during the 1980s, see Steigum (1992a) and Johnsen et al. (1992).

[14] Source: OECD Historical Statistics 1960-1990.

Norwegian portfolio, and Thonstad (1981) proposed the design of government budget policy rules contingent on the future oil price. However, these suggestions were not reflected in the economic policy during the period 1980-1986.

3.3. Adjustment problems after the oil price plunge in 1986

The oil price drop during the winter of 1985-1986 (figure 7) had a dramatic impact on the Norwegian economy. Government petroleum revenues deteriorated sharply. In combination with private debt accumulation this gave rise to a dramatic worsening of the current account (figure 5). As a consequence, a fiscal policy restraint reducing aggregate demand was implemented in order to fight the internal and external deficits and to turn the ongoing structural adjustment process, i.e. trigger a re-entry of traditional industries producing tradeables.[15] Two important reports, "Stortingsmelding nr. 46 (1986-87)" and NOU 1988:21 (the report of the "perspective group"), discussed elements in this process and, more generally, economic policies after the oil price drop.

"Stortingsmelding nr. 46" considered the impact of the low and uncertain oil price level on extraction and development of new fields. In response to production cuts in other petroleum producing countries, the report presented the government decision to reduce the production level with 7.5% in order to contribute to lower oil supply and a higher oil price. The basic message of this report was that more attention should be paid to the presence of uncertainty. A main argument was that existing plans proposing a high and intensified investment level in the petroleum sector would increase the oil dependency to an even higher level. Therefore the report recommended a slower and more gradual development of new fields together with a maintenance of the exploration activities.

The report of the "perspective group" started out by recognizing that economic policies during the previous years had been myopic and that the risk of oil price

[15] A theoretical analysis of such a recovery from the "dutch disease", is given by Steigum (1992b) and Thøgersen (1994a).

drops had been underestimated (p. 10). By calling attention to the huge current account deficits, the consumption level of the economy was deemed as not sustainable. In order to restore a stable growth path of the economy a structural re-entry process had to take place. The report advocated a fiscal restraint as well as supply side reforms in order to improve the efficiency of the economy.

The perspective group highlighted the concept of the national wealth and argued that the ongoing extraction combined with a deccumulation of the foreign assets indicated a reduction in the national wealth and lower welfare for future generations. This view was supported by the calculations of several estimates of the petroleum wealth based on alternative assumptions of the oil price path and production trajectories. Given historical prices and current expectations, it seemed that the petroleum wealth had deteriorated during the 1980s. Hence, the report recommended increased saving, and this was to a large extent motivated by the expected increase in the expenditures related to the financing of the social security system.[16]

Compared to previous government reports, the report of the perspective group discussed extensively how the government should deal with the risk-exposure to oil price fluctuations. Firstly, the group repeated the recommendation from NOU 1983:27 that parts of the petroleum revenues should be allocated to foreign financial assets in order to shelter the economy from fluctuations in the oil price. Secondly, the report referred to the development of international financial markets and claimed that participation in these markets by the Norwegian government could contribute to an efficient diversification of the risks related to the petroleum wealth. It was pointed out that the development of a huge mainland supply industry for the petroleum sector had increased the risk exposure and that a further expansion of this industry would contribute to even higher vulnerabilty.

[16] The Norwegian social security system was established in 1967. It is essentially financed on a pay-as-you-go basis. The expenditures on the system are expected to increase due to a gradual phase-in of the old-age pensions and the ageing of the population.

The report also discussed the design of contingent policy rules and strategies related to oil price fluctuations.

When the oil price dropped, the need for reductions in aggregate demand and improvements in the current account was soon reflected in actual policy. After a chaotic centralized wage bargaining process which resulted in large wage increases, the government carried out a 10% devaluation in May 1986. A fiscal restraint was passed later in the year and new restraints followed in 1987 and 1988. Since private sector had accumulated a considerable debt, the effect of reduced deductibility of interest payments was of particular importance. This added to the effect of increased nominal interest rates and implied a significant increase in the after tax real interest rate.[17] Another element in the contractionary policy was the passing of a temporary wage regulation law during the period from March 1988 to April 1990.

Considerable effects of the restrictive policies appeared rather quickly. Real disposable income of the households declined in 1987 and was approximately constant during the next two years. Private savings started to increase and private real investments decreased. This could to a large extent be attributed to the increase in the after tax real interest rate which gave rise to negative substitution and wealth effects for representative Norwegian households with net debt. As a consequence, private consumption decreased and stagnated at a new and lower level, see figure 3. This figure also illustrates that the restraint hit private sector only. Government consumption continued to grow. The joint effect of increased private saving, lower private investments and a high growth in petroleum production following the 1988 abolishment of the transistory production limitations from 1986 (figure 8), implied a surprisingly fast improvement of the current account. In fact the current account balance was positive in 1989 (figure 5).

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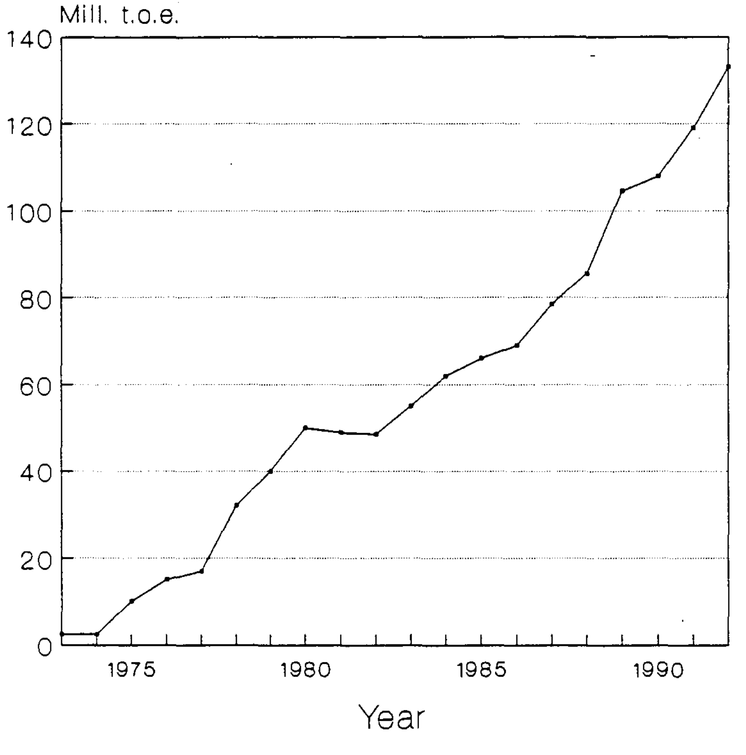
[17] The nominal interest rate was in fact kept at an artificially low level until December 1986 when the defending of the fixed exchange rate triggered increases, see Steigum (1992a).

Figure 8 **Total Norwegian petroleum production 1973-1992**
Source: The Norwegian Petroleum Directorate, the annual report of 1992.

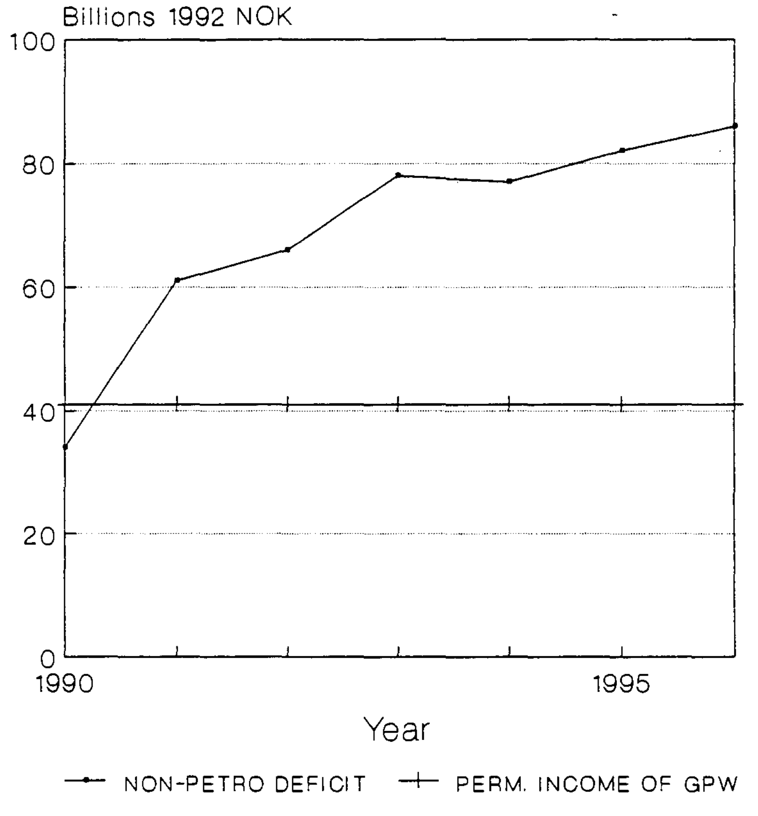


A severe and persistent recession started in 1988 and involved low economic growth (figure 2) and increased unemployment. In order to fight these problems the contractionary policies were gradually turned to expansionary ones after 1989. Increased government consumption and tax cuts following a reform of the Norwegian tax system, implied a total fiscal stimulus in the period 1989-1992 which exceeded the total restraint in the period 1986-1988 (according to the Ministry of Finance). Correspondingly, the central government budget deficit increased, exceeding 40 billions NOK in 1993 (figure 6). Still, the expansionary effects on private consumption and investments were small in 1989-1993, and the unemployment rate approached a level of 6% of the working force.[18] The stagnation of aggregate demand was related to low private real investments and an increasing level of private saving. This was probably due to both the high after tax real interest rate and an operative precautionary saving motive associated with for example the risk of being unemployed or, more generally, the uncertainty in the future levels of labor income and social security benefits. It was also hard to trigger a re-entry of industries producing tradeables. The government strongly advocated the need for improvements in relative unit labor costs, and following the recommendations in the report of the "Employment Commission" (NOU 1992:26), the labor unions agreed to moderate wage increases during the first part of 1990s. As indicated in figure 4, the relative unit labor costs have decreased, but in 1993 there was still no significant expansion of these industries.

During the 1990s increased attention has been directed to the sustainability of fiscal policy. The problem was illustrated by calculations in the Revised National Budget for 1992 ("Stortingsmelding nr. 2 (1991-92)") which showed that the estimated permanent income of the government petroleum wealth was much smaller than the projected non-petrolem deficits (figure 9). Hence, the present budget policy seemed to imply fiscal restraints in the future and, disregarding perfect altruism between generations, an intergenerational allocation of welfare from future

[18] Including persons allocated to labor market measures, the unemployment rate in 1993 was approximately 9% of the working force.

Figure 9 **The non-petroleum deficit (forecasts for 1992-1996) and the estimated permanent income of the government petroleum wealth (GPW).**
Source: The Revised National Budget for 1992



generations to the present.[19] This problem has been addressed in the Long Term Program for 1994-1997 ("Stortingsmelding nr. 4 (1992-93)") and the National Budget for 1994 ("Stortingsmelding nr. 1 (1993-94)") where the need for smaller deficits was clearly stated. At the same time the government worried about the low activity level in the economy and the persistent high unemployment. The government has therefore tried to combine these concerns by the pursuing of the "Solidarity-alternative" which involves a continuation of the cooperation in the income policy aimed at further improvements in relative unit labor costs and reduced government transfers to the private sector.[20] The objective underlying the latter reduction has been to contribute partly to lower deficits and partly to increased government investments in infrastructure and education.

While the risk exposure to oil price fluctuations was carefully discussed in the report of the perspective group and to some extent in "Stortingsmelding nr. 46 (1986-87)", this issue still receive negligible attention in real policy. Figure 8 shows that the extraction has increased sharply since 1986 despite earlier recommendations which strongly propose a slower and more gradual development of new fields. It is interesting to note that the extraction level of 90 millions t.o.e. once regarded as an appropriate upper limit, was quickly passed in 1988. An extraction level of 132 millions t.o.e was reached in 1992, and according to the Long Term Program for 1994-1997 the extraction will continue to increase until a peak level of slightly more than 160 millions t.o.e. is reached at the end of this decade. Obviously, the government budget and the current account are extremely vulnerable to oil price fluctuations. Still, the possibilities of diversifying the oil price risk by participation in the international financial market have not been investigated by the government. Additionally, the latest adjustments of the petroleum tax system

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[19] A theoretical analysis of the effects of budget deficits on intergenerational welfare in open economies is given by Persson (1985). A numerical analysis of the intergenerational effects of the spending of petroleum revenues and the budget policy in Norway is given by Steigum and Thøgersen (1994).

[20] The "Solidarity alternative" term was introduced by the "Employment Commision" (NOU 1992:26).

have increased the risk exposure to an even higher level.[21] A petroleum fund was implemented in January 1990, but no rules or strategies for the long run accumulation and spending of the petroleum revenues were presented. The guidelines of the fund established a close link between the contemporaneous government budget and the accumulation of the fund, and due to the budget deficits in the first part of the 1990s no fund has been accumulated so far.[22]

4. FUTURE PETROLEUM REVENUES AND THE ECONOMIC DEVELOPMENT

Beyond year 2000 the petroleum sector is expected to be gradually phased out during a time span of several decades. According to the Long Term Program for 1994-1997, the investment level is expected to fall rather sharply after 2000, while the net cash flow from the sector will decline moderately after 2005. How the remaining petroleum wealth, recently estimated to 820 billions NOK or 117% of GDP in 1992 (using a 7% discount rate), will contribute to the welfare of present and future generations, depends to a large extent on the economic policy in the near future.

At the present stage (1994) the Norwegian economy seems to be improving. After some years of stagnation, aggregate demand increases due primarily to strong growth in private consumption. The unemployment rate has been stabilized and even reduced slightly. As reported in the National Budget for 1995 ("Stortingsmelding nr. 1 (1994-95)"), the budget deficit has declined from 1993 to 1994 and is expected to decline further in 1995. While tax increases in 1994 and an announced cut in government expenditures as a percentage of GDP in 1995 contribute to this development, the main reason is increasing tax revenues caused by the improvement of the business cycle and higher government petroleum revenues. Whether the present prosperity is followed by decades of sustainable growth without

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21 A discussion of Norwegian petroleum taxation and government risk exposure is given by Osmundsen (1994).

22 The guidelines of the petroleum fund are discussed in the Revised National Budget for 1990 ("Stortingsmelding nr. 2 (1989-90)").

serious fiscal restraints and periods of stagnation, depends among other things on (1.) the long run strategies for spending of government petroleum revenues and budget policy, (2.) the ability to deal with petroleum price risk and (3.) the ability to solve the adjustment problems associated with re-entries of mainland industries producing tradeables.

A first attempt to analyse the impact of the present fiscal policy on the net tax burdens of the present and future generations is provided by Auerbach et al. (1993) in their generational accounts for Norway. In contrast to the traditional budget deficit figures, the generational accounts are forward-looking in the sense that changes in the petroleum wealth and future increases in the expenditures on the social security system are taken into account. Auerbach et al. finds a considerable intergenerational imbalance. A continuation of the present fiscal policy is calculated to leave future generations with a net tax burden twice as large as the burden of the present children. These calculations are subject to uncertainty in the long run projection of various variables, but the basic message is clear. The combination of the current fiscal policy, a gradual phase-out of the petroleum revenues after 2005 and the aging of the population implies an expected future choice between severe fiscal restraints or a smaller welfare state. In the National Budget for 1995 ("Stortingsmelding nr. 1 (1994-95)") updated calculations of the generational accounts are presented. These new figures reveal almost the same intergenerational imbalance as the original calculations.

Potential problems related to the financing of the government sector in the future are in a weaker sense also recognized in the Long Term Program for 1994-1997 (published prior to the generational accounts). The "Solidarity alternative" calls for lower growth in government consumption and reduced subsidies to private production sectors. Still, central government financial assets including capitalization of direct investments in state enterprises are expected to be reduced from a level exceeding 30% of GDP in 1990 to near zero before 2000. The Long Term Program does not provide any analysis of the impact of this policy on the net tax burden of future generations.

Focusing on the intergenerational allocation of the government petroleum revenues means that there is a need for explicit long run strategies for fiscal policy and distribution of net tax burdens between generations. This implies that the scope for intergenerational progressive taxation must be evaluated. It is therefore necessary to analyze how international integration leading to increased mobility of capital and to some extent labor, limits the tax base and increases the excess burden (see Hagen (1993)). In order to make long run strategies related to the net tax burdens of different generations operational, the traditional national account figures should be supplemented by calculations of the intergenerational effects of the actual policy. One possibility is to present generational accounts figures in for example the national budgets. A potential problem in the priority of long run considerations is related to the political institution and the impact of political instability and pressure group activity (see SOU 1993:16). The existence of a clearly stated strategy for the budget policy and explicit calculations showing the intergenerational effects of the actual policy may contribute to increased discipline in the budget process.

A persistent negative oil price shock will increase the intergenerational imbalance to a higher level and trigger more restrictive fiscal policies. In the light of the experiences after the oil price drop in 1986, this calls for policies dealing with the risk exposure to oil price fluctuations. Attention must be paid to how uncertainty in government petroleum revenues influences private sector. As a consequence of the government risk exposure to oil price fluctuations, private sector is facing uncertainty in the level of future taxes, government transfers and publicly provided goods.[23]

There is a gap between previous recommendations to reduce the government risk exposure to oil price fluctuations and the lack of attempts to diversify this risk. This suggests a closer investigation of the actual possibilities of increased diversification. The relevant risk for a marginal petroleum field is (from a national point of

[23] We note that expansionary fiscal policy financed by intensified petroleum extraction may have counterintuitive effects since a higher risk exposure increases the level of precautionary saving, see Thøgersen (1993).

view) given by the covariance between the return from the field, which is closely linked to the oil price, and macroeconomic target variables as national income and consumption (see Lund (1987)). Therefore, a negative correlation between oil price changes and consumption growth in most petroleum-importing countries (Obstfeld (1993)) indicates that the value of a marginal petroleum field in the North-Sea is higher for these countries than for Norway.[24] This means that an international trade in claims to resources in the North-Sea could, at least in principle, benefit both Norwegian citizens as well as investors in the international financial market (see Thøgersen (1994b)). Naturally, trade in such claims may be subject to problems related to the absence of enforceable contracts (see footnote 2), but it is still interesting to evaluate carefully the opportunities to share the oil price risk through participation in the rather developed international financial market of the 1990s.

A possible step towards reduced government petroleum dependency may include sale of shares in Statoil (the government petroleum company) to international investors and a corresponding government accumulation of other non-petroleum assets. Another interesting and more indirect approach to increased diversification would be to alter the current pricing practice for gas along the lines proposed by Golombek and Hoel (1987). Usually, the long run gas contracts are based on pricing formulas which establish a positive relation between the price of gas and the price of oil. According to Golombek and Hoel an efficient contract should, however, be characterized by a negative relation between the prices of gas and oil. This would diversify the oil price risk for both Norway as a net exporter of both oil and gas and importing countries like Germany which are net importers of both products. Hence, the risk aspect deserves attention in the negotiations of the gas contracts.

The current level of unemployment indicates that the structural adjustment

[24] Obstfeld (1993) calculates the correlation coefficient between the change in the log real price of crude oil and the change in the log of world real per capita consumption to -0.6.

problems revealed after the oil price drop in 1986 has not yet been solved. The expected decline in the activity level of the petroleum sector adds to this problem, and the Norwegian economy is therefore expected to be characterized by considerable structural adjustments in the decades to come. The success of this process depends on the ability to deal with adjustment problems associated with transfers of capital and labor between sectors. A favourable development in the cost competitiveness of the mainland industries is necessary in order to both boost re-entries of industries producing tradeables and increase the possibilities of the present supply industry to export their products and services. As highlighted in the "Solidarity alternative", further gains in relative unit labor costs will promote efficient structural changes. A lesson from the 1970s should also be mentioned. Recognizing that structural adjustments have to take place, government tax reductions and subsidies targeted to industries in declining sectors may prevent structural adjustments.

5. FINAL REMARKS

The first part of this paper discusses the calculation of the Norwegian petroleum wealth. Looking at the fluctuations in the wealth estimates, the uncertainty facing the decisionmakers in the management of the petroleum wealth is striking. We proceed with a survey of economic policy and macroeconomic performance since the beginning of the 1970s. The development of the petroleum sector and the spending of the petroleum revenues have contributed positively to growth and national income.[25] While a severe recession hit other countries in the first part of the 1970s, the activity level was kept high and the unemployment rate low as a consequence of the phase-in of the petroleum sector and expansionary fiscal policies based on the existence of petroleum resources to be extracted in the following years. During the 1980s high petroleum revenues initiated an accumulation of government financial assets exceeding 13% of GDP in 1986. Due to this

[25] Using a small macroeconometric model, Cappelen and Gjelsvik (1990) analyze the impact of the oil sector on the Norwegian economy.

informal petroleum fund the government has so far financed the budget deficits of the early 1990s without an accumulation of net debt.

Still, the petroleum era has been characterized by adjustment problems and business cycle fluctuations. The resource boom in the middle of the 1970s was followed by economic restraints at the end of the same decade, and the prosperity in the middle of the 1980s was brutally interrupted by the oil price crash in 1986. We also note that the growth rate for private consumption has fluctuated widely, while government consumption has increased steadily (figure 3). The relative growth in private consumption during the whole period 1973-1990 was roughly equal in Norway and OECD-Europe while government consumption increased by 96% in Norway compared to only 52% in OECD-Europe (see table 3).

	Norway	OECD-Europe
Private consumption	54%	53%
Government consumption	96%	52%
Total consumption	60%	53%
Total investments	14%	33%

Table 3 Growth in consumption and investment in Norway and OECD-Europe 1973-1990.
Source: Skånland (1992)

A persistent re-entry problem related to the need for an expansion of traditional industries producing tradeables was revealed after the oil price drop in 1986. Additionally, recent calculations of generational accounts indicate that the expansionary fiscal policies in the beginning of the 1990s are not sustainable and may lead to huge increases in the net tax burden of future generations. After 2005 the net cash flow from the petroleum sector is expected to decline, and the aging of the population will gradually increase the expenditures to the financing of the social security system. Whether the petroleum wealth will contribute to increased welfare for future generations depends among other things on the ability to reduce the government risk exposure to oil price fluctuations, to solve the structural adjustment problems and to commit to long run sustainable strategies for budget policy and spending of the petroleum revenues.

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ESSAY 2

UNCERTAIN PETROLEUM REVENUES, THE GOVERNMENT BUDGET AND PRECAUTIONARY SAVING*

ABSTRACT

This paper deals with the effects of uncertain government petroleum revenues on fiscal policy, wealth accumulation and intergenerational welfare in a small open economy. A relationship between the uncertain government petroleum revenues and the tax level gives rise to precautionary saving among the households. Depending on the petroleum production trajectory and fiscal policy, different generations face different risks regarding their future tax burden, and this affects private saving. The effect of a one period tax cut followed by tax increases in order to stabilize the expected government wealth depends on whether the tax cut is financed by intensified petroleum extraction in the following period(s). This will trigger increased precautionary saving which may offset the wealth effect of the tax policy on the consumption of present generations.

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1. INTRODUCTION

In this paper we consider a small open overlapping generations economy where the government is endowed with an uncertain petroleum wealth. The only source of uncertainty is non-diversified resource price uncertainty. While tax risk to some extent is present in all economies, a special feature of a petroleum economy is that the presumably very large tax risk caused by fluctuations in the government petroleum revenues is distributed between generations according to extraction policy and fiscal policy. Depending on the policy choices, different generations may therefore face completely different risks regarding their future tax burden. Since precautionary saving seems to be an important source of total wealth accumulation (Skinner (1988), Caballero (1991)), such variations in the incentives of the different generations to engage in precautionary saving may lead to considerable variations in wealth accumulation. A tax cut financed by intensified extraction alters the intergenerational allocation of risk, and we will demonstrate that this triggers increased precautionary saving which may offset the wealth effect on the consumption of present generations.

Norway with its large petroleum resources is an illustrating example of the type of economies we analyze. As in most resource economies, government resource ownership is an appropriate description. In fact more than 80% of the petroleum revenues are collected by the government (through direct ownership of the reserves or indirectly through taxation), and an estimate of the *government* petroleum wealth amounts to 113% of GDP in 1993. Therefore volatile petroleum revenues due to oil price shocks trigger substantial fluctuations in the government budget deficit or surplus. After 1988 Norway experienced a fiscal expansion and simultaneously sharp increases in the petroleum production. Still private demand stagnated, while private saving increased substantially. We believe that our analysis of a tax cut financed by intensified extraction will shed light on this development.

This paper is in the spirit of Bertola and Drazen (1993). They show how a cut in government spending may alter the expectations of future policy changes and thereby lead to an expansion. Focusing on the link between fiscal policy, tax risk and precautionary saving, this paper provides an alternative explanation to counterintuitive effects of fiscal policy. The link between fiscal policy and precautionary saving among households has previously been analyzed by Chan (1983), Barsky et al. (1986) and Kimball and Mankiw (1989). Assuming heterogenous individuals who live at the same time and face idiosyncratic gross income risk, these authors show that future taxes provide insurance if the tax liability of an individual is positively correlated with his gross income. Thus, a tax cut coupled with increased income tax in the future (levied on the same individuals) has expansionary effects since this policy lowers the variance of future net income. Contrary to these articles, we assume that the representative individual in each generation in each period faces tax risk, and our analysis focuses on how fiscal policy and the choice of the petroleum production trajectory influence the risk of different generations.[1] Since future oil prices are highly uncertain, intensified extraction provides less insurance against sudden oil price shocks and corresponding fluctuations in the tax level.

In the next section we present our model. Adressing intergenerational issues, it is natural to choose an overlapping generations model as the vehicle of analysis, see for example Diamond (1965) and Persson (1985). Our model is an extended version of Persson's small open economy model without private intergenerational transfers. Uncertain government petroleum revenues are taken into account, and the existence of a relationship between these uncertain revenues and the tax level gives rise to precautionary saving among the households. We assume a constant absolute risk aversion utility function which permits a very illustrative and simple solution to the consumption/saving problem of the households, see Caballero (1990, 1991). In this case precautionary saving in every future period can be calculated deterministically even though future net income and consumption are

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1 To some extent this paper is also related to Gordon and Varian (1988) who show how government budget policy may improve the intergenerational allocation of risk. However, Gordon and Varian do not address the relationship between tax risk and precautionary saving.

stochastic. Section 3 analyzes the wealth accumulation and explains how the level of precautionary saving evolves over time. In section 4 we consider government budget policy. We study the effects of a one period tax reduction which is financed by intensified extraction of the petroleum resources and therefore implies no short run decumulation of government financial wealth. The last section concludes.

2. AN OVERLAPPING GENERATIONS MODEL

We consider a small open petroleum economy which has access to a perfect international capital market with a strictly positive constant world real interest rate, r, for risk-free borrowing and lending. Time is discrete. Each generation lives in two periods, so in every period there are two generations, a "young" and an "old". There is no population growth (although it could easiliy be introduced), and we will also disregard technical progress. Both generations participate in the labor market, and each individual supplies one unit of labor inelastically. During the time interval between the initial period 0 and the period of exhaustion, T, the government receives uncertain revenues from petroleum extraction. After this presumably long-lasting transition the uncertainty is completely revealed, and the economy will reach a deterministic and stationary steady state.

2.1. Production

The production side of the model is kept as simple as possible. There is no production in government sector except for petroleum, and we assume no use of labor in the extraction activities. Private output (Y_t) is produced by a strictly concave, constant returns to scale neoclassical production function $F(K_t,L_t)$, where K_t is private real capital and L_t is the labor supply. Defining $y_t=Y_t/L_t$ and $k_t=K_t/L_t$, we obtain $y_t=f(k_t)$, $f'>0$, $f''<0$. Assuming perfect competition, no taxation of profits and a constant rate of real capital depreciation equal to δ, maximization of profits implies $f'(k_t)=r+\delta$ and $w_t=f(k_t)-k_tf'(k_t)$ where w_t is the gross wage. Therefore k_t and w_t are determined by the constant $r+\delta$, and we obtain $k_t=k$ and $w_t=w$ in all periods t. Since L_t is given by the constant total population, the capital stock, K_t, is also constant in all periods.

2.2. Government wealth and taxes

Turning to the government sector, we express all quantity variables in per capita units. In period 0 the expected government petroleum wealth is given by

$$(1) \qquad E_0(PW_0) = \sum_{t=0}^{T} \frac{[E_0(p_t)]x_t}{(1+r)^t} ,$$

where p_t is the stochastic net petroleum price in period t, x_t the petroleum production and E_0 denotes the expectation conditional on information available in the beginning of period 0. The exogenous total stock of resources to be extracted is normalized to one, so x_t can be interpreted as the share to be extracted in period t, $\Sigma^T_{t=0}\, x_t=1$. We assume that x_t is given by a politically chosen depletion policy. Due to technological constraints it seems reasonable to disregard the possibility of changing x_t after p_t has been observed. The net petroleum price follows a first order autoregressive process:

$$(2) \qquad p_{t+1} = p + \beta(p_t - p) + \varepsilon_{t+1}.$$

Here p is the expected net price level in the long run, the parameter β measures the degree of persistence in the price shocks, $0<\beta<1$, and ε_{t+1} is an independent and identically distributed random variable.[2] The value of ε_{t+1} is observed in the beginning of period $t+1$. We will assume that ε_{t+1} is normally distributed, ε_{t+1}~$N(0,\sigma^2)$.

Period 0 is the initial period, and as a point of departure we assume that $p_0=p$, i.e. $\varepsilon_0=0$. In the beginning of period 0 the expected petroleum wealth s periods later is

$$(3) \qquad E_0(PW_s) = \sum_{t=s}^{T} \frac{px_t}{(1+r)^{t-s}} , \; s=0,1,....,T .$$

Then, p_1 is observed in the beginning of period 1, and the realization of ε_1 causes a

[2] The assumption of a constant expected petroleum price in the long run is in accordance with the latest assumptions made by the Norwegian government (see "Stortingsmelding nr. 4 (1992-93)" by the Norwegian Ministry of Finance).

revision of expected future prices. Using (2), we obtain

$$(4) \qquad E_1(PW_1) = \sum_{t=1}^{T} \frac{(p + \beta^{t-1}\varepsilon_1)x_t}{(1+r)^{t-1}} .$$

The impact of ε_1 depends crucially on the persistence properties measured by β. A price shock has long lasting effects on future petroleum revenues if β approaches one and minor effects if β approaches zero.[3]

From (3) and (4), it follows that the change in the expected petroleum wealth between period *0* and period *1* is given by

$$(5) \qquad E_1(PW_1) - E_0(PW_0) = -px_0 + r\left(\sum_{t=1}^{T} \frac{px_t}{(1+r)^t}\right) + \sum_{t=1}^{T} \frac{(\beta^{t-1}\varepsilon_1)x_t}{(1+r)^{t-1}}.$$

The first term on the right reflects that the revenues from extraction in period *0* contribute to a lower petroleum wealth. The second term is given by the period *0* expected return from the remaining wealth in the beginning of period *1*, and this "discounting effect" is positive. The last term is the present value of expected changes in future revenues following the realization of ε_1. In period *0* the expected value of this last term is by definition zero. The sign of the net effect is ambiguous, even in the absence of changes in the expectations. Thus, positive petroleum production does not necessarily imply a decumulation of the expected petroleum wealth.

We note that $E_{t+1}(PW_{t+1})-E_t(PW_t)$ can be expressed by equations analogous with (5) for all $t=0,1,...,T$. How a change in the expected government petroleum wealth influences future fiscal policy depends on the contemporary fiscal policy and accumulation of other government assets. We must therefore turn our attention to the dynamic path of total government wealth, Ω_t. Abstracting from government

3 Recent work by Green et al. (1993) suggests that particularly the large petroleum price shocks associated with wars in the Middle East or other major events have very strong persistence properties.

real capital, we have

(6) $$\Omega_t = B_t + PW_t.$$

Here B_t is government financial assets in the beginning of period t, and

(7) $$B_{t+1} = (1+r)B_t + (1+r)p_t x_t + \tau_t - G_t,$$

where τ_t is tax revenues and G_t government expenditures in period t. For simplicity we assume that G_t is fixed and constant in every period, G_t=G.

In order to model the link between uncertain petroleum revenues and fiscal policy (i.e. tax policy since G is constant), we assume as a benchmark that the choice of τ_t ensures $E_t(\Omega_{t+1})-E_t(\Omega_t)=0$ in all periods t (note that the expectations are conditional on information in period t and not $t+1$). Whether such a tax policy is a result of any optimization procedure by the government is not essential here, but our assumption seems appropriate due to two characteristics. Firstly, this policy implies a negative relationship between a price shock (ε_t) and τ_t. Secondly, it implies tax smoothing in the sense that a transitory shock in the government petroleum revenues gives a small permanent change in the tax level. In section 4 we will consider the intergenerational effects of a policy which involves $E_t(\Omega_{t+1})-E_t(\Omega_t)<0$ in some periods.

In period 0 the expected change in total wealth between period 0 and 1 is, from (6), (7) and (3),

(8) $$E_0(\Omega_1) - E_0(\Omega_0) = r[B_0 + E_0(PW_0)] + \tau_0 - G.$$

Accordingly, when $E_0(\Omega_1)-E_0(\Omega_0)=0$, rearranging (8) yields

(9) $$\tau_0 = G_0 - r[B_0 + E_0(PW_0)].$$

Thus, τ_0 is equal to G minus the return from the expected total government wealth. Regarding the petroleum revenues in period 0 it follows implicitly from this policy that revenues in excess of the return from the period 0 expected remaining petroleum wealth are allocated to government financial assets (increasing B_1), i.e. a petroleum fund is accumulated (see (5) and remember $E_0(\varepsilon_1)=0$). If the petroleum revenues are smaller than the return from the expected remaining petroleum wealth, the government runs a financial deficit.

The realization of ε_1 calls for a tax adjustment in period 1. It is not difficult to verify that $E_1(\Omega_2)-E_1(\Omega_1)=r[B_1+E_1(PW_1)]+\tau_1-G$ and that $E_1(\Omega_2)-E_1(\Omega_1)=0$ implies $\tau_1=G-r[B_1+E_1(PW_1)]$ (analogous to (8) and (9)). In order to compare τ_0 and τ_1 we use (2) and (7), and it follows that

$$(10)\qquad E_1(\Omega_2)-E_1(\Omega_1) = r[(1+r)B_0+(1+r)p^*x_0+\tau_0-G]+\tau_1-G+r\left(\sum_{t=1}^{T}\frac{(p^*+\beta^{t-1}\varepsilon_1)x_t}{(1+r)^{t-1}}\right).$$

When $E_1(\Omega_2)-E_1(\Omega_1)=0$, equation (10) implies

$$(11)\qquad \tau_1 = G - r[B_0 + E_0(PW_0)] - r\Gamma_1\varepsilon_1,\quad \Gamma_1 = \sum_{t=1}^{T}\frac{\beta^{t-1}x_t}{(1+r)^{t-1}}.$$

If we compare equation (9) and equation (11), we see that the tax adjustment is given by the last term on the RHS of (11). This term, $r\Gamma_1\varepsilon_1$, reflects the return from the change in total government wealth caused by the effect of ε_1 on present and future petroleum revenues. The larger the value of β and the higher the petroleum production in the present period and the nearest future (compared to production in the distant future), the higher is Γ_1, and the stronger is the negative relationship between ε_1 and τ_1. We may interpret Γ_1 as a measure of the degree of exposure to petroleum price uncertainty in period 1.

In the following periods new price shocks imply new tax adjustments, and by repeating the same type of calculations as above we can derive τ_t, $t=2,3,\dots,T$. In period 2, it follows that

$$\tau_2 = G - r[B_0 + E_0(PW_0)] - r[\Gamma_1\varepsilon_1 + \Gamma_2\varepsilon_2],\ \ \Gamma_2 = \sum_{t=2}^{T}\frac{\beta^{t-2}x_t}{(1+r)^{t-2}}, \tag{12}$$

and if we generalize, we obtain

$$\tau_t = G - r[B_0 + E_0(PW_0)] - r\left(\sum_{s=1}^{t}\Gamma_s\varepsilon_s\right),\ \ \Gamma_s = \sum_{j=s}^{T}\frac{\beta^{j-s}x_j}{(1+r)^{j-s}}. \tag{13}$$

Each new period is characterized by an additional adjustment term which causes fluctuations in the tax level. After period T the economy is no longer exposed to petroleum price shocks, and the tax rate is stabilized, $\tau_{T+z}=\tau$ $(z=0,1,2,...)$. Naturally, government wealth is stabilized as well, $\Omega_{T+z+1}=B_{T+z+1}=B$.

2.3. The households

The consumption of a representative young person in period t is

$$C_{1,t} = w - \tau_t - S_t, \tag{14}$$

where S_t is saving. In the second period of the life cycle, the consumption of this person is given by

$$C_{2,t+1} = w - \tau_{t+1} + (1+r)S_t. \tag{15}$$

It follows from (14) and (15) that taxes are lump-sum and that we neglect bequest.[4] If we define the net wage in period t as $w^n_t \equiv w-\tau_t$, we notice that (11)-(13) imply $w^n_{t+1}=w^n_t+r\Gamma_{t+1}\varepsilon_{t+1}$. After period T constant taxes imply $w^n_{T+z}=w^n$ $(z=0,1,2,...)$. Since $\varepsilon_{t+1}\sim N(0,\sigma^2)$, we have

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[4] Within the framework of overlapping generations, the implications of different types of taxation are analyzed by for example Atkinson and Sandmo (1980) and Auerbach and Kotlikoff (1987). An overlapping generations model which incorporate a "joy-of-giving" bequest motive is analyzed by Steigum (1993).

$$(16) \qquad r\Gamma_{t+1}\varepsilon_{t+1} \sim N\left(0,\ (r\Gamma_{t+1})^2\sigma^2\right).$$

The representative young person in period t chooses S_t in order to maximize expected utility given by

$$(17) \qquad E_t(U_t) = u(C_{1,t}) + \frac{1}{(1+\rho)}E[u(C_{2,t+1})],$$

where ρ is the rate of time preference and $u'>0$, $u''<0$. In addition we assume that uncertain income implies precautionary saving, i.e. increased uncertainty leads to a steeper slope of the expected consumption path over the life cycle. As we know from the literature on saving decisions under uncertainty, this means that the preferences must be characterized by convex marginal utility, $u'''>0$, which is a weaker condition than non-increasing absolute risk aversion.[5] In order to obtain a simple and illustrative closed form solution to the consumption/saving problem, we specify a constant absolute risk aversion (CARA) utility function[6]

$$(18) \qquad u(C_{i,t}) = -\frac{1}{\theta}e^{-\theta C_{it}},\ i=1,2\ .$$

Here θ is the coefficient of absolute risk aversion.

Maximizing (17) subject to (14), (15) and (18) gives the first order condition

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5 See for example Leland (1968), Sandmo (1970), Blanchard and Mankiw (1988) and Caballero (1991).

6 CARA utility implies that there is no distinction between risk aversion and the intertemporal elasticity of substitution, and within the traditional expected utility framework, other more general specifications of the utility function yield no closed form solution. Recently, Weil (1993) has presented a tractable model of precautionary saving based on non-expected utility preferences which are iso-elastic intertemporarily and exponential in the risk dimension. He shows that the level of precautionary saving is positively related to the degree of risk aversion and negatively to the degree of intertemporal substitution. In this paper we focus on the basic positive relationship between net income risk and precautionary saving, however, and the main results hinge on the rather plausible assumption $u'''>0$, not on the CARA specification.

(19) $$e^{-\theta C_{1,t}} = \frac{1+r}{1+\rho} E\left(e^{-\theta C_{2,t+1}}\right).$$

For simplicity we assume $r=\rho$. Since the term $r\Gamma_{t+1}\varepsilon_{t+1}$ is normally distributed, see (16), reorganizing gives[7]

(20) $$C_{2,t+1} = C_{1,t} + \frac{1}{2}\theta(r\Gamma_{t+1})^2\sigma^2 + r\Gamma_{t+1}\varepsilon_{t+1} ,$$

and it follows that higher price uncertainty measured by σ^2 implies a steeper expected consumption path. Solving for S_t yields

(21) $$S_t = \frac{\theta}{2(2+r)}(r\Gamma_{t+1})^2\sigma^2 .$$

A higher level of price uncertainty (higher σ^2) and higher values of θ and Γ_{t+1} increase S_t. Due to our assumptions it follows that the precautionary motive is the only operative saving motive in the model. After the uncertainty is revealed in period T, the precautionary motive is no longer relevant. In addition there is no need for life cycle saving because w^n_{T+z} is constant ($z=0,1,2,...$) and the optimal consumption path flat, $C_{1,T+z}=C_{2,T+z+1}$. Hence, $S_{T+z}=0$.

3. WEALTH ACCUMULATION

3.1. Private wealth

We define A_t as private non-human wealth per capita in the beginning of period t. Since there are two generations, we have $A_{t+1}=S_t/2$. After the uncertainty is revealed in period T, the economy reaches a steady state and $A_{T+1+z}=0$ ($z=0,1,...$). During the transition $A_t>0 (t=1,2,...,T)$, and it follows from (21) that higher values of θ, σ^2 and Γ_t give a higher A_t. For a given value of β, the chosen production trajectory determines the "degree of exposure", Γ_t, and it is of particular interest to study how different trajectories imply different dynamic paths for A_t.

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[7] Generally, we use the fact that $x \sim N[E(x), \sigma_x^2]$ implies $E(e^x)=e^a$, $a=E(x)+0.5\sigma_x^2$.

Using (21), it follows that

$$(22) \qquad A_{t+1} - A_t = \frac{\theta}{4(2+r)} r^2\sigma^2[(\Gamma_{t+1})^2 - (\Gamma_t)^2] ,$$

and the sign of A_{t+1}-A_t is given by the sign of Γ_{t+1}-Γ_t. Since

$$(23) \qquad \Gamma_{t+1} - \Gamma_t = -x_t + \frac{1+r-\beta}{1+r}\Gamma_{t+1} ,$$

the production in period t tends to lower the change in risk exposure between period t and period $t+1$, while the effect of future production coming closer in time tends to increase this exposure (the second term on the RHS of (23)). The net effect is ambiguous, and neither the sign of Γ_{t+1}-Γ_t nor the sign of A_{t+1}-A_t could be determined without knowledge of the production path.

We will consider three different production trajectories in order to gain further insights into the relationship between the chosen trajectory and the accumulation of private wealth. First we consider a completely flat trajectory, $x_t=x$ $(t=0,1,...,T)$. Using the definition of Γ_t and applying the formula of a finite geometric series gives

$$(24) \qquad \Gamma_t = \frac{x\left(\frac{\beta^{T-t+1}}{(1+r)^{T-t+1}} - 1\right)}{\frac{\beta}{1+r} - 1} .$$

Since $0<(\beta/(1+r))<1$, we obtain $\Gamma_1>\Gamma_2>...>\Gamma_T>0$, and A_t is decreasing over time.

Consider now the case of a production trajectory which declines geometrically, $x_t=\lambda^t x_0$, $0<\lambda<1$, $t=0,1,...,T$. We assume that the resources are exhausted during a given finite number of periods, i.e. the values of λ and x_0 satisfy $\Sigma^T_{t=0} x_t=1$. Applying the formula of a finite geometric series gives

$$(25) \qquad \Gamma_t = \lambda^t x_0 \cdot \frac{\left(\frac{\lambda\beta^{T-t+1}}{(1+r)^{T-t+1}} - 1\right)}{\frac{\beta\lambda}{1+r} - 1},$$

which not surprisingly implies $\Gamma_1 > \Gamma_2 > ... > \Gamma_T$, and a decreasing A_t over time.

In the last case we assume a geometrically increasing production trajectory, $x_t = \lambda^t x_0$, $\lambda > 1$, $t = 0,1,...,T$. We still assume values of λ and x_0 which ensure $\Sigma^T_{t=0} x_t = 1$. The only change from the previous case is the value of λ, and Γ_t is still given by (25). In this case $\lambda > 1$ implies that the first term on the RHS of (25), $\lambda^t x_0$, is increasing over time. However, the second term, the fraction, is decreasing, and the sign of $\Gamma_{t+1} - \Gamma_t$ is therefore undetermined. Numerical calculations based on reasonable assumptions typically indicate that $\Gamma_{t+1} - \Gamma_t$ is first positive in some periods and then negative in later periods preceding and including period T. Therefore A_t is typically first increasing and then decreasing. It is also possible to construct examples which give either an increasing or a decreasing path for Γ_t (and then for A_t) in all periods. Generally a combination of a very low β and a very high λ gives a monotonically decreasing Γ_t, while the opposite combination gives a monotonically increasing Γ_t.

Three stylized numerical examples based on the assumptions given in table 1 illustrate the types of production trajectories considered and the corresponding normalized paths for A_t.

	production	r	β	T	x_0	λ
CASE A	$x_t = x$	0.07	0.8	9	0.1	-
CASE B	$x_t = x_0\lambda^t$, $0 < \lambda < 1$	0.07	0.8	9	0.224*	0.8
CASE C	$x_t = x_0\lambda^t$, $\lambda > 1$	0.07	0.8	9	0.039*	1.2

Table 1 Assumptions used in the numerical calculations.

* We have calculated $x_0 = (\lambda - 1)/(\lambda^{T+1} - 1)$ which ensures $\Sigma^T_{t=0} x_t = 1$.

Figure 1 illustrates the trajectories, while figure 2 illustrates the dynamic paths for A_t. Case A considers a flat trajectory, and as figure 2 shows, there are minor decreases in A_t during the first periods. Then A_t falls more sharply as the period of exhaustion comes closer. This means that the two terms on the RHS of (23) almost offset each other in the first periods, but then the negative effect of x_t dominates. Case B considers a geometrically declining trajectory, and the figures show that both x_t and A_t decline sharply. In case C, the geometrically increasing trajectory, the figures illustrate that increasing production triggers increases in A_t until period *6*. From period *7* the effect of no future risk exposure after period T dominates the effect of increasing production, and A_t decreases.

3.2. National wealth and the current account

The non-human national wealth per capita in the beginning of period t is given by

$$\text{(26a)} \qquad NW_t = PW_t + B_t + A_t.$$

The impact of uncertain petroleum prices on NW_t follows from both the evolution of A_t and the stochastic shocks in government wealth ($\Omega_t = PW_t + B_t$) directly related to the price shocks. The realization of price shocks will affect Ω_t but not the deterministic path for A_t. In period *1* we have $E_1(\Omega_1 - \Omega_T) = 0$ due to the described tax policy. Therefore $E_1(NW_1 - NW_{T+1}) < 0$ since $A_t > 0$ during the transition $(t = 1, 2, \ldots, T)$ and $A_{T+1+z} = 0$ $(z = 0, 1, \ldots)$. Naturally, NW_{T+1+z} is constant.

Alternatively, NW_t can be expressed as

$$\text{(26b)} \qquad NW_t = PW_t + F_t + k,$$

where F_t is foreign assets per capita, $F_t = A_t + B_t - k$. The current account surplus per capita in period t is (since k is constant) given by

$$\text{(27)} \qquad F_{t+1} - F_t = (A_{t+1} - A_t) + (B_{t+1} - B_t).$$

Figure 1 **Production trajectories**

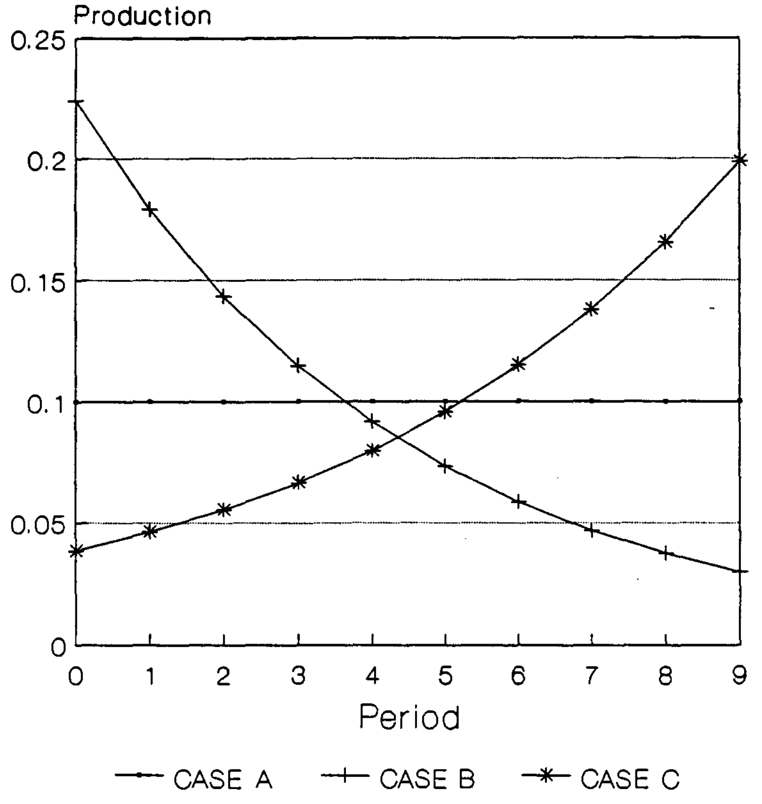
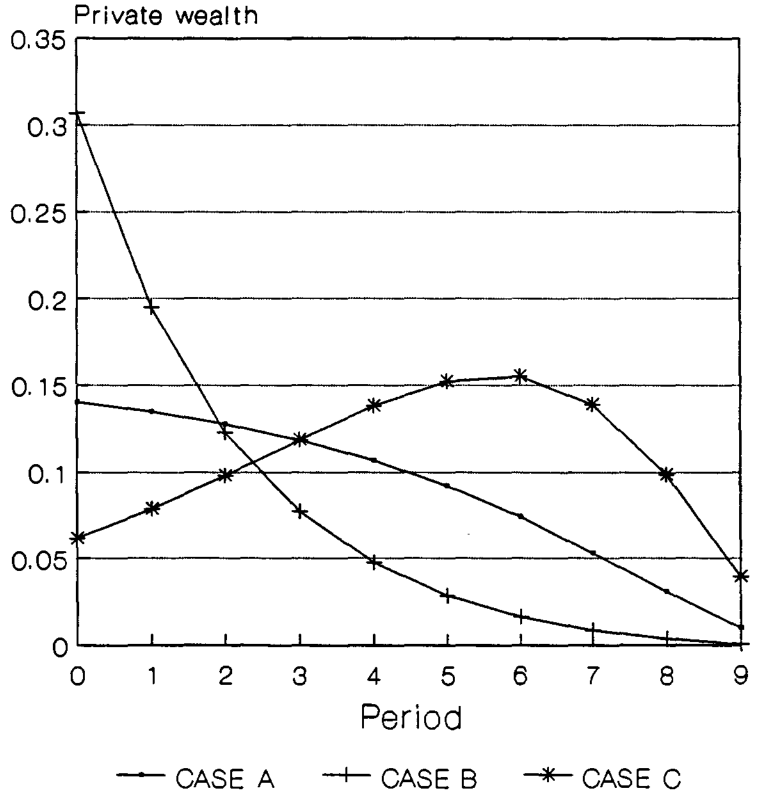


Figure 2 **Private non-human wealth**



The government petroleum revenues contribute to increases in this surplus through increases in B_{t+1}. In some periods with high and increasing petroleum production a high risk exposure may, as we have seen, also give a positive value of $(A_{t+1}-A_t)$. This effect will eventually increase the surplus. Still, if we consider the whole transition, the net accumulated decrease in A_t $((A_{T+1}-A_1)<0)$ creates a wedge between $(F_{T+1}-F_1)$ and $(B_{T+1}-B_1)$.

4. BUDGET POLICY

In order to finance a temporary budget deficit the government must choose an appropriate combination of a decumulation of its financial assets and a lower petroleum wealth through intensified extraction of the petroleum resources. While traditional debt financing has wealth effects on present and future generations, a fiscal expansion coupled with intensified petroleum extraction has both wealth effects and effects following from the reallocation of tax risk between generations. We will argue that the financing of deficits through intensified extraction is a very tempting policy option. Imagine, for example, a policy maker who feels that the government petroleum resources justify a tax cut but who simultaneously wants to avoid any serious long-lasting decumulation of government financial assets. Since the petroleum wealth is excluded from the definition of wealth in the National Accounts in most countries, the traditional definition of the government budget deficit does not take changes in the petroleum wealth into account, and therefore this policy experiment may look rather favourable, at least in the short run. Increased attention to the well known Maastricht criteria which present rather ambitious requirements to the financial position of the government (as reported in the National Accounts) may add to this tendency.

4.1. A baseline experiment

As a baseline policy experiment we study the effects of a tax reduction in period *0* while we keep the petroleum production trajectory unchanged. This policy implies a reduction in B_1 and therefore tax increases in the following periods in order to obtain $E_t(\Omega_{t+1})-E_t(\Omega_t)=0$, $t=1,2,...$. In the following we use an asterisk "*" in connection with a variable to denote the value of the variable after the effect of the policy experiment has been taken into account. The tax reduction per capita in period *0* due to the policy experiment is $\tau_0-\tau_0^*=TR_0$, and the corresponding decrease in government wealth is $B_1-B_1^*=\Omega_1-\Omega_1^*=TR_0$. In the following periods stabilization of government wealth implies tax increases equal to $\tau_t^*-\tau_t=rTR_0$, $t=1,2,...$.

It follows immediately that the consumption of the representative old consumer in period *0* will increase, $C_{2,0}^*-C_{2,0}=TR_0$. Since $r=\rho$ and since the preferences given by (18) implies that the level of precautionary saving is independent of the (net) income level, it is also apparent that the consumption of both the young generation in period *1* and all the following generations will decrease, $C_{1,t}-C_{1,t}^*=C_{2,t+1}-C_{2,t+1}^*=rTR_0$ $(t=1,2,...)$. Private savings in period *1* and in the following periods are not influenced by the policy experiment since the production trajectory (and then the risk exposure) is unchanged, $S_t^*=S_t$ $(t=1,2,...)$.

The young generation in period *0* experiences both the tax reduction in period *0* and the (smaller) tax increase in period *1*. Solving the consumption/saving problem of the representative individual in this generation, gives

$$(28) \qquad S_0^* = \frac{\theta}{2(2+r)}(r\Gamma_1)^2\sigma^2 + \frac{(1+r)}{(2+r)}TR_0 \ ,$$

where the last term on the RHS is the increase in saving due to the policy experiment (compare equation (21)). The net gain from the tax changes in the two periods is smoothed across both periods of the life cycle, $C_{1,0}^*-C_{1,0}=C_{2,1}^*-C_{2,1}=(TR_0/(2+r))$.

Clearly, this policy experiment increases the welfare of the two generations alive in period *0* while the welfare of all the following generations decreases. The permanent decrease in government wealth implies a two step reduction in national wealth. In the beginning of period *1*, we have

(29) $$(NW_1\text{-}NW_1^*) = (PW_1\text{-}PW_1^*) + (A_1\text{-}A_1^*) + (B_1\text{-}B_1^*),$$

and the term $(PW_1\text{-}PW_1^*)$ is equal to zero since the petroleum production trajectory is not altered. Increased saving by the young generation in period 0 implies $(A_1\text{-}A_1^*)<0$, and it follows that $(NW_1\text{-}NW_1^*)<(B_1\text{-}B_1^*)$. We have seen that this increase in private saving is temporary and therefore $(NW_t\text{-}NW_t^*)=(B_t\text{-}B_t^*)$ for $t=2,3,....$ We also note that this two step reduction in national wealth corresponds with similar decreases in the foreign assets.

4.2. A tax cut financed by increased petroleum production

We now turn to a policy experiment which involves a tax reduction in period 0 accompanied by increased petroleum production in period 1. As mentioned in the introduction, this experiment can be motivated by the economic policy in Norway after 1988. The experiment corresponds with the previous baseline experiment, but in addition we assume that the government decides to increase the petroleum production in order to rapidly counteract the decumulation of government financial wealth caused by the tax cut. Due to technological constraints it seems reasonable to assume that the production increase decided in period 0 is operative in period 1. The production increase is chosen in order to give the government an expected increase in petroleum revenues equal to the period 1 value of the tax cut, i.e.

(30) $$[x_1^{**} - x_1][E_0(p_1)\text{-}\psi] = (1+r)TR_0,$$

where the double asterisk (**) denotes that the effect of the second policy experiment has been taken into account. The variable ψ denotes the per unit adjustment cost related to the short run manipulation of the predetermined production trajectory. To keep things simple and to facilitate comparison with the baseline policy experiment, we assume that the total adjustment costs is equal to the period 1 expected value of reallocating the production increase from future periods to period 1.[8] This means that $E_0(PW_1)$ is unaffected by the manipulation of the production trajectory, and we can abstract from any effect of a change in the size of the expected petroleum wealth.

As in the baseline experiment, it follows immediately that the consumption of the representative old individual in period 0 will increase, $C_{2,0}^{**}-C_{2,0}=TR_0$. The behaviour of the following generations is influenced by the change in the production trajectory. The production increase in period 1, $x_1^{**}>x_1$, means that $x_t^{**}<x_t$ for at least one t ($t=2,3,\ldots,T$). For simplicity we assume $x_t^{**}<x_t$ for all $t=2,3,\ldots,T$, i.e. the production reduction after period 1 is smoothed over time. Then by the definition of Γ_t (see equation (13)) and $0<\beta<1$, it follows that $d\Gamma_1/dx_1>0$ and $d\Gamma_t/dx_1<0$ ($t=2,3,\ldots,T$). Hence, $\Gamma_1^{**}-\Gamma_1>0$ and $\Gamma_t^{**}-\Gamma_t<0$ ($t=2,3,\ldots,T$).

If we look at the young generation in period 1 and the following generations, a lower degree of risk exposure means that $S_t^{**}<S_t$, $t=1,2,\ldots,T-1$. The expected tax increases, $E_0[\tau_t^{**}-\tau_t]=rTR_0$ ($t=1,2,\ldots$), tend to reduce the expected consumption level, while the lower level of precautionary saving until period T implies a smoother consumption path during the two period life cycle.[9] Hence, we obtain $E_0[C_{2,t}^{**}-C_{2,t}]<0$ and $E_0[(C_{1,t}^{**}+C_{2,t}^{**})-(C_{1,t}+C_{2,t})]<0$ for $t=2,3,\ldots$. The sign of $E_0[C_{1,t}^{**}-C_{1,t}]$ is indeterminate for $t=1,2,\ldots T-1$ and strictly negative for $t\geq T$.

The behaviour of the young generation in period 0 is influenced by both the tax cut in period 0, the expected tax increase in period 1 and the increase in risk exposure in period 1. Solving the consumption/saving problem of the representative young individual in period 0, yields

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8 This expected value is positive since $r>0$ and $E_0(p_t)=p$ for all t. Note that there are no adjustment costs related to the decrease in production in later periods.

9 In the baseline policy experiment we considered $\tau_t^{*}-\tau_t$, while we consider $E_0(\tau_t^{**}-\tau_t)$ in this experiment. The distinction follows from the fact that the risk exposure is changed in this experiment but not in the first.

(31) $$S_0^{**} = \frac{\theta}{2(2+r)}(r\Gamma_1^{**})^2\sigma^2 + \frac{(1+r)}{(2+r)}TR_0 ,$$

and we obtain $S_0^{**}>S_0^{*}>S_0$ (see (21) and (28)). This means that $E_0(C_{2,1}^{**})>E_0(C_{2,1}^{*})> E_0(C_{2,1})$. It also follows that

(32) $$C_{1,0}^{**}-C_{1,0} = \frac{TR_0}{2+r} - \frac{\theta}{(2(2+r)}r^2\sigma^2[(\Gamma_1^{**})^2 - (\Gamma_1)^2],$$

and the sign of this expression is undetermined since the effect of increased risk exposure on current consumption is negative (the second term on the RHS). Then the sign of $E_0[(C_{1,0}^{**}+C_{2,0}^{**})-(C_{1,0}+C_{2,0})]$ is undetermined as well. A chief conclusion is therefore that the expansionary effect of a tax cut on current consumption may be (partly) offset by increased precautionary saving if the risk exposure increases along with the tax cut.

This second policy experiment increases the welfare of the old generation in period *0* and decreases the expected welfare of the young generation in period *T* and all the following generations. Regarding the young generation in period *0*, the net reduction in total expected taxes over the life cycle tends to increase expected welfare while the increase in precautionary saving has the opposite effect. The net effect is indeterminate. The effect on the welfare of the generations born in the periods *1,2,...,T-1* is also indeterminate due to lower precautionary saving but a higher expected tax level.

If we look at the (period *0*) expected impact of this policy experiment on the national wealth in the beginning of period *1*, we find that the reduction in government wealth contributes to a lower national wealth while the transitory increase in private wealth has the opposite effect. The increase in private wealth is higher than in the baseline experiment, and the expected net effect on national wealth in the beginning of period *1* may even be positive. From the beginning of period *2* to the beginning of period *T*, both the permanent expected decrease in government wealth and the decrease in private wealth contribute to a lower expected national wealth. Therefore the expected decrease in national wealth is larger than in the baseline experiment during these periods. We note that the increased petroleum production in period *1* has no effect on expected national wealth or expected total government wealth, but it has a transitory positive effect on government financial assets and foreign financial assets. In period *T* these improvements due to the manipulation of the trajectory are expected to disappear.

5. FINAL REMARKS

This paper has analyzed some effects of uncertain government petroleum revenues in a small open overlapping generations economy. A relationship between the uncertain government petroleum revenues and the tax level implies that the households engage in precautionary saving. The choice of a petroleum production trajectory determines how the degree of exposure to the uncertain revenues varies over time. Different generations may therefore face different risks regarding their future tax burden, and this leads to variations in private wealth accumulation. We studied government budget policy, and we demonstrated that the expansionary effects of a tax cut on current consumption may more or less disappear if the tax cut indirectly leads to a higher risk exposure through intensified extraction of the petroleum resources.

Throughout this paper we have assumed that the uncertainty related to the petroleum revenues is non-diversified. This assumption seems appropriate if we look at the lack of attempts to diversify the large petroleum related risks in the national portfolios in many petroleum economies. However, the rapid growth and development of international financial markets during the last decade has probably improved the possibility of risk sharing through global diversification.[10] How petroleum economies can benefit from increased participation in these markets, is an important question, and it deserves attention from both policy makers and economists.

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[10] See Obstfeld (1992) for an analysis which demontrates how international risk sharing may imply substantial welfare gains.

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ESSAY 3

INTERNATIONAL DIVERSIFICATION AND OIL PRICE RISK*

ABSTRACT

This paper deals with the effects of oil price risk on international risk sharing. We consider both petroleum importing and exporting countries within OECD-Europe. The empirical analysis indicates that uninsured idiosyncratic oil price risk accounts for parts of the observed low consumption correlation between these countries. This result suggests that both petroleum exporters and importers could benefit from innovations in the markets for claims to unextracted oil and natural gas, for example long run forward contracts for crude oil or gas contracts characterized by a negative relation between the prices of gas and oil.

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1. INTRODUCTION

This short paper analyzes the impact of oil price risk on international diversification within OECD-Europe. In a world economy characterized by high international capital mobility and complete markets, per capita consumption growth should be syncronized across countries and should not respond to any idiosyncratic risks. Still, existing empirical studies show rather low correlations between consumption growth in different countries. This suggests missing markets or restrictions on international asset trade.[1] The hypothesis investigated in this paper is that uninsured idiosyncratic oil price risk contributes to the explanation of these findings.[2]

Within OECD-Europe the exposure of the different countries to oil price fluctuations varies along with the huge variations in their dependency on oil and natural gas imports (the gas price is closely linked to the oil price). We consider a sample of five countries in OECD-Europe: Norway, the Netherlands, Germany, France and Denmark. Norway is among the world's largest net exporters of oil and gas, and the Netherlands is a major gas exporter. On the other hand, Germany and France have only negligible petroleum resources. Denmark has increased its oil production during the recent years, but during the years considered in our empirical analysis the production was low and the significance of the Danish petroleum wealth not recognized. The different countries could in principle benefit from a reduction or elimination of their idiosyncratic oil price risk through trade in state contingent assets. At the present stage the relevant futures markets are incomplete, however. Oil futures have maturity dates no longer than a year ahead, and the lack of markets for oil to be extracted further into the future may be explained by the absence of enforceable contracts (Lund (1987, 1990)). Gas is sold through long term contracts, but in these contracts the price is typically given by a formula linking the gas price closely to the oil price (Golombek and Hoel (1987)). Hence,

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1 See for example Obstfeld (1993, 1994), Backus, Kehoe and Kydland (1992, 1993), Stockman and Tesar (1993) and Baxter and Crucini (1993).

2 In addition OECD-Europe may, as a total net importer of petroleum, face aggregate oil price uncertainty.

we suspect that the idiosyncratic oil price risk is uninsured.

The empirical analysis is based on a methodological framework developed by Obstfeld (1993).[3] This framework makes it possible to discriminate empirically between the effects of potentially uninsured (and maybe uninsurable) idiosyncratic oil price risk and restrictions on international asset trade. Obstfeld's paper deals only to a limited extent with the effects of oil price risk. He finds that idiosyncratic oil price risk does not explain much of the differences in the consumption growth in each of the seven largest industrial countries and the average consumption growth in a group of 47 countries. Since most major petroleum importing countries are included in this group and most major exporters are omitted, this result does not shed much light on whether oil price risk is traded between importers and exporters of petroleum. Thus, we want to extend Obstfeld's analysis in this direction.

The next section presents the model framework and the econometric specification. The results are reported in section 3. Our analysis shows that uninsured idiosyncratic oil price risk accounts for part of the observed low consumption correlations between the countries considered. Section 4 concludes and suggests some possible approaches that the different countries could pursue in order to benefit from increased diversification of this risk.

2. METHODOLOGY

2.1. Analytical framework

Following Obstfeld (1993), we consider a representative infinitely-lived individual in country i, $i=1,2,\ldots,N$. In period $t=0$ this individual maximizes

[3] This framework is in turn related to the models of Cochrane (1991) and Mace (1991).

(1) $$U_0 = E\left(\sum_{t=0}^{\infty} (\delta_i)^t u(C_{i,t},\theta_{i,t}) \mid s_0\right),$$

where δ_i is the rate of time preference, $C_{i,t}$ is consumption (of a single tradeable consumption good), $\theta_{i,t}$ is a preference shock and the period utility function $u(\cdot)$ satisfies $u'>0$ and $u''<0$. For every period t there is a set of possible states of nature, and s_t is the realized state. The probability that state s_t is realized depends on the value of s_{t-1} and possibly on time. Thus, we assume a Markov structure, and $E\{\cdot \mid s_t\}$ is the expectation conditional on the information observed up to period t. The maximization of (1) is subject to feasibility constraints for each period and in each state.

Markets may be incomplete in the sense that contracts can be made contingent on only a subset of the future possible states of nature. Assuming that the representative individuals in country i and j ($i \neq j$) have rational expectations and face identical asset prices, it can be proven that the solution to their maximization problems is characterized by the theorem (see Obstfeld p. 7):

"The date t+1 ex post marginal rate of intertemporal substitution difference between any two countries i and j,

(2) $$D_{i,j}(s_{t+1},s_t) = \frac{\delta_i u'[C_i(s_{t+1}),\theta_{i,t+1}]}{u'[C_i(s_t),\theta_{i,t}]} - \frac{\delta_j u'[C_j(s_{t+1}),\theta_{j,t+1}]}{u'[C_j(s_t),\theta_{j,t}]},$$

is statistically uncorrelated with any random variable on which date t+1 contracts can be written, as well as with any variables realized on date t or before."

In the case of complete markets, this theorem implies that $D_{i,j}(s_{t+1},s_t)=0$, i.e. the marginal rates of intertemporal substitution are equalized. In the opposite case of no trade at all in contingent contracts, it follows that $E[D_{i,j}(s_{t+1},s_t) \mid s_t]=0$, i.e. $D_{i,j}(s_{t+1},s_t)$ is uncorrelated with period t information but correlated with period $t+1$ information. Of course, in the intermediate cases characterized by a limited trade in state contingent assets, $D_{i,j}(s_{t+1},s_t)$ is correlated with some period $t+1$ variables.

2.2. Econometric specification and data

In order to obtain a tractable econometric specification, assume an isoelastic period utility function,

$$(3) \qquad u(C_{i,t},\theta_{i,t}) = \frac{1}{1-\rho}(C_{i,t})^{1-\rho} \cdot e^{\theta_{it}} ,$$

where ρ is the common coefficient of relative risk aversion. Under complete markets $D_{i,j}(s_{t+1},s_t)=0$. When we define $t=0$ as the initial period and normalize $\theta_{i,0}$ so $\theta_{i,0}=0$ for any country i, it follows after simple manipulations that

$$(4) \qquad logC_{i,t} = logC_{j,t} + \log\left(\frac{C_{i,0}}{C_{j,0}}\right) + \frac{t}{\rho}\cdot\left(\log\frac{\delta_i}{\delta_j}\right) + \frac{1}{\rho}(\theta_{i,t}-\theta_{j,t}) .$$

Since we will allow for some uninsurable idiosyncratic risks, we add an error term to the RHS of (4). Then, differencing yields the following link between the change in the log of per capita consumption in country i and country j:

$$(5) \qquad \Delta logC_{i,t} = \lambda + \Delta logC_{j,t} + \gamma_t + \varepsilon_t .$$

Here $\Delta logC_{i,t} \equiv logC_{i,t} - logC_{i,t-1}$, λ is a constant ($\lambda=(1/\rho)log(\delta_i/\delta_j)$, γ_t is uninsurable period t innovations and ε_t is a stationary disturbance term which reflects taste shocks and errors in measuring consumption.

Under complete markets all idiosyncratic risks are insured, and the term γ_t vanishes. Hence, we may run regressions of the type

$$(6) \qquad \Delta logC_{i,t} = \lambda + \alpha_{ij}\Delta logC_{j,t} + \varepsilon_t ,$$

for all countries i and j ($i \neq j$) and test the hyphothesis that $\alpha_{ij}=1$.

If markets are incomplete, the variables subject to idiosyncratic shocks, i.e. the variables underlying γ_t in (6), should enter significantly into the regression model. Since we suspect the oil price, OP_t, to be an important uninsured idiosyncratic variable, we may estimate the equation

$$(7) \qquad \Delta logC_{i,t} = \lambda + \alpha_{ij}\Delta logC_{j,t} + \beta_{ij}\Delta logOP_t + \varepsilon_t \ ,$$

and test whether β_{ij} is significantly different from zero. In the regressions of (6) and (7) we specify the dependent variable $\Delta logC_{i,t}$ for the petroleum exporting countries Norway and the Netherlands respectively and the explanatory variable $\Delta logC_{j,t}$ for the petroleum importing countries Germany, Denmark and France. This implies that the sign of β_{ij} should be positive, i.e. a high value of $\Delta logOP_t$ benefits the petroleum exporting countries. In addition α_{ij} should increase in response to the inclusion of $\Delta logOP_t$ since the estimate of α_{ij} based on equation (6) is downward biased if $\beta_{ij}>0$ and $COV(\Delta logOP_t\,,\ \Delta logC_{j,t})<0$.[4] If the financial markets are perfectly integrated, we will obtain $\alpha_{ij}=1$ once the uninsurable variables are included in the regression equation. We will therefore expect values of α_{ij} closer to one and β_{ij} significantly greater than zero after $\Delta logOP_t$ has been included in the model.

Based on annual data from 1973-1988 we estimated equation (6) and equation (7) for the various combinations of the countries considered. Like Obstfeld (1993) we use real per capita consumption data measured in 1985 international prices from the Penn World Table Mark 5 data base, see Summers and Heston (1991) for a documentation. The real crude oil prices (deflated by the U.S. consumer price index) were obtained from Green, Mork and Vaage (1993). The data are listed in an appendix.

3. EMPIRICAL RESULTS

As a point of departure, we calculated the correlation coefficients between $\Delta logC_{i,t}$ and $\Delta logC_{j,t}$ for all combinations of countries in our sample, see table 1. The correlations are in the range from 0.12 in the case of France versus Norway to 0.80

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[4] Using ′ to denote coefficients estimated from equation (6), which omits $\Delta logOP_t$, we have $E(\alpha_{ij}')=\alpha_{ij}+(\beta_{ij}\cdot\psi)$ where ψ is the slope in the regression of $\Delta logOP_t$ on $\Delta logC_{j,t}$, see for example Gujarati (1988).

in the case of the Netherlands versus Germany. The typical figure is around 0.4-0.5. These magnitudes are much lower than the unit correlations associated with complete markets and free international asset trade. Still, they are in line with other consumption correlations presented in the recent literature for various combinations of industrialized countries during the post 1970 era (see the references in footnote 1).

Country *i*:	Germany	Norway	France	Denmark	The Netherlands
Country *j*:					
Germany	1	-	-	-	-
Norway	0.15	1	-	-	-
France	0.44	0.12	1	-	-
Denmark	0.42	0.53	0.52	1	-
The Netherlands	0.80	0.38	0.50	0.46	1

Table 1 **Correlations between $\Delta logC_{i,t}$ and $\Delta logC_{j,t}$ - Annual data 1973-1988**

Turning to the effects of oil price risk, we first look at the results involving Norway versus Germany, Denmark and France, see table 2. We note that Norway experienced a sharp credit expansion and a corresponding consumption and investment boom following the ending of credit rationing in 1985, see Steigum (1992). In order to account for the rather extreme adjustment effects of this credit boom, we introduced a dummy variable taking the value one in 1985 and 1986 and else zero. The coefficient of this dummy is positive and highly significant in all the regressions. In all three cases the inclusion of $\Delta logOP_t$ increases the coefficient of determination adjusted for degrees of freedom and the coefficient of $\Delta logC_{j,t}$ which comes closer to one. This indicates that uninsured oil price risk explains parts of the rather low consumption correlations between Norway and each of the petroleum importers. In the case of Norway versus Denmark our results are rather robust since the coefficients of both $\Delta logOP_t$ and $\Delta logC_{j,t}$ are significantly larger than zero at a 5% level once $\Delta logOP_t$ is included. In the case of Norway versus Germany the significance of these coefficients is weaker ($p<0.25$) and especially in the case of Norway versus France the lack of significance is striking ($p<0.25$ for the coefficient of $\Delta logOP_t$ only).

Country *j*:	Coeff. of $\Delta logC_{j,t}$	Coeff. of $\Delta logOP_t$	Coeff. of dummy	r^2 adj. for d.f.	DW
Germany	0.25 (0.42, p>0.25)	-	0.050 (0.021, p<0.05)	21.6%	1.25
Germany	0.44 (0.43, p<0.25)	0.026 (0.020, p<0.25)	0.062 (0.022, p<0.01)	25.4%	1.37
Denmark	0.38 (0.22, p<0.10)	-	0.037 (0.020, p<0.05)	34.5%	1.73
Denmark	0.63 (0.21, p<0.01)	0.042 (0.017, p<0.05)	0.050 (0.018, p<0.01)	53.2%	2.29
France	0.16 (0.55, p>0.25)	-	0.049 (0.021, p<0.05)	20.0%	1.26
France	0.37 (0.58, p>0.25)	0.023 (0.021, p<0.25)	0.060 (0.023, p<0.05)	21.7%	1.41

Table 2 **Results of regressions based on (6) and (7) - Dependent variable: $\Delta logC_{i,t}$, *i*=Norway**

Note: 1. Standard errors of coefficients and p-values for an upper tailed t-test (coeff. =0 against >0) are shown in parentheses.
2. A dummy variable (equal to one in 1985 and 1986, else zero) has been included in the regression in order to account for the effects of the ending of the credit rationing in Norway.
3. Critical lower and upper bounds for the DW statistic are $d_L=0.982/d_U=1.539$ in the regressions which omit $\Delta logOP_t$ and $d_L=0.857/d_U=1.728$ in the regressions of the complete equation.

Table 3 shows that the results involving the Netherlands versus the petroleum importing countries reveal mainly similar patterns as the results studied above. In order to correct for first order autocorrelation in the cases of the Netherlands versus Denmark and France respectively, the regressions were performed by an iterative Cochrane Orcutt procedure. We see that the inclusion of $\Delta logOP_t$ increases the coefficient of determination adjusted for degrees of freedom and the coefficient of $\Delta logC_{j,t}$ in all the cases. While the latter coefficient comes closer to one in the cases of the Netherlands versus Denmark and France, it actually increases from 1.05 to 1.21 in the case of the Netherlands versus Germany. However, 95%

confidence intervals around both 1.05 and 1.21 include one. In the case of the Netherlands versus Germany the coefficients of both $\Delta logOP_t$ and $\Delta logC_{j,t}$ are significantly greater than zero at a 5% level. Almost similar results appear in the case of the Netherlands versus Denmark. The coefficient of $\Delta logOP_t$ is significantly greater than zero at a 5% level, and the coefficient of $\Delta logC_{j,t}$ is significantly greater than zero at a 5% level once $\Delta logOP_t$ has been included. In the case of the Netherlands versus France the significance is weaker, p<0.25 for the coefficient of $\Delta logOP_t$ and p<0.10 for the coefficient of $\Delta logC_{j,t}$ once $\Delta logOP_t$ is included.

Country j:	Coeff. of $\Delta logC_{j,t}$	Coeff. of $\Delta logOP_t$	r^2 adj. for d.f.	DW
Germany	1.05 (0.21, p<0.01)	-	61.6%	1.46
Germany	1.21 (0.19, p<0.01)	0.021 (0.0078, p<0.05)	73.1%	1.40
Denmark	0.17 (0.11, p<0.10)	-	55.5%	0.73/1.38
Denmark	0.34 (0.14, p<0.05)	0.018 (0.0092, p<0.05)	62.6%	0.67/1.12
France	0.26 (0.26, p<0.25)	-	51.7%	1.04/1.31
France	0.46 (0.32, p<0.10)	0.010 (0.0096, p<0.25)	52.1%	0.97/1.16

Table 3 **Results of regressions based on (6) and (7) - Dependent variable: $\Delta logC_{i,t}$, i=The Netherlands**

Note: 1. Standard errors of coefficients and p-values for an upper tailed t-test (coeff. =0 against >0) are shown in parentheses.
2. The regressions involving Denmark and France have been performed by an iterative Cochrane Orcutt procedure in order to correct for first order autocorrelation. The DW statistics before and after correction are shown. Critical lower and upper bounds for the DW statistic are d_L=1.106/d_U=1.371 in the regressions which omit $\Delta logOP_t$ and d_L=0.982/d_U=1.539 in the regressions of the complete equation.

4. FINAL REMARKS

Our analysis supports the view that uninsured oil price risk explains parts of the rather low consumption correlations between European countries. Still, it is fair to say that the statistical results are not overwhelming in all cases. We can offer four possible explanations of the modest precision in some of the regressions. Firstly, we have only considered oil price risk. An inclusion of other idiosyncratic variables may improve the statistical results. Secondly, the results may reflect that many of the countries in our sample maintained capital controls early in the time period considered. Thirdly, the size of the petroleum sector in the Netherlands and Norway has varied over time. While the petroleum sector has increased in Norway during 1973-1988, the significance of the natural gas sector in the Netherlands has gradually declined in this period. We will therefore conjecture that adding post 1988 observations to our data set will increase the coefficient of $\Delta logOP_t$ in the regressions involving Norway and decrease it in the regressions involving the Netherlands.

Finally, the regression equations have been derived under the assumptions of time additive isoelastic utility and a single tradeable consumption good. Ideally, a more general utility function and both traded and non-traded goods should be considered, but tractable econometric spesifications based on such assumptions have not yet been derived. Various authors have constructed equilibrium business cycles models allowing for a distinction between tradeables and non-tradeables (among others see Backus, Kehoe and Kydland (1992)), but neither these models succeed in the explanation of the observed consumption correlations, see the survey by Obstfeld (1994).

Accepting that uninsured oil price risk explains parts of the low consumption correlations means that petroleum exporters and importers could benefit from innovations in the market for claims to unextracted oil and natural gas. Serious contract problems may be present in a world market for claims to unextracted petroleum, for example due to political risks. Still, we will argue that the design of bilateral forward contracts between the governments in politically stable and closely related European countries may be realistic. A recommendation by Golombek and Hoel (1987) is particularly appealing. They analyze the design of efficient gas contracts and show that the gas price should be negatively related to the oil price. Such gas contracts will reduce the idiosyncratic oil price risk for countries producing both oil and gas as well as for countries importing both petroleum products.

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APPENDIX

Real consumption per capita (1985 international prices)

Year	Germany	Norway	Denmark	France	The Netherlands
1972	5333.96	4463.01	5337.95	5423.63	5515.99
1973	5469.89	4559.34	5563.11	5667.36	5739.45
1974	5498.52	4706.25	5378.38	5701.43	5914.45
1975	5696.88	4920.63	5557.31	5838.77	6036.98
1976	5920.64	5195.14	5976.21	6090.09	6327.13
1977	6166.25	5531.71	6019.06	6223.58	6614.57
1978	6391.47	5420.62	6040.58	6418.21	6868.21
1979	6600.97	5566.03	6103.76	6573.92	7031.92
1980	6641.46	5654.05	5868.73	6610.95	6986.24
1981	6577.44	5669.72	5710.68	6700.41	6762.18
1982	6479.64	5712.71	5775.11	6883.37	6646.64
1983	6599.23	5736.33	5905.54	6874.46	6683.09
1984	6709.16	5844.81	6083.37	6895.51	6724.79
1985	6801.26	6364.24	6357.79	7015.58	6855.31
1986	7015.76	6672.66	6595.04	7235.10	6998.08
1987	7250.98	6581.07	6502.20	7394.21	7159.09
1988	7461.65	6402.37	6420.93	7564.80	7193.68

Source: The Penn World Table (Mark 5), variable 3 and 6, see Summers and Heston (1991).

Crude oil Prices (nominal and 1985 real prices)

Year:	Nominal (USD/bbl)	Real (1985 USD/bbl)	Year:	Nominal (USD/bbl)	Real (1985 USD/bbl)
1972	2.48	6.38	1981	32.00	37.82
1973	2.75	6.66	1982	34.00	37.88
1974	10.84	23.66	1983	31.50	34.01
1975	10.46	20.92	1984	29.00	30.02
1976	11.51	21.77	1985	28.50	28.50
1977	12.40	22.01	1986	14.37	14.09
1978	12.70	20.94	1987	18.62	17.60
1979	15.67	23.21	1988	14.94	13.60
1980	27.00	35.23			

Source: Green, Mork and Vaage (1993), the nominal prices are deflated by the U.S. consumer price index.

ESSAY 4

PETROLEUM WEALTH, DEBT POLICY AND INTERGENERATIONAL WELFARE: THE CASE OF NORWAY*

(Co-author: Erling Steigum, Jr.)

ABSTRACT

What happens to the welfare of present and future generations in Norway if the petroleum wealth of the central government is consumed in the course of the next forty years? By simulating a computable overlapping generations model, this paper illustrates the magnitudes that are likely to be involved. Due to the Norwegian government's huge wealth, the scope for intergenerational redistribution through debt policy is much greater in Norway than in most other countries in the OECD. Our results indicate that a wealth consumption policy has serious and long-lasting negative effects on the welfare of the present very young generations and generations that are not yet born.

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1. INTRODUCTION

This paper deals with long-run effects of government debt policy on the welfare of future generations in a small open economy, using Norway as an illustration. In neoclassical growth models with overlapping generations of life cycle savers, a permanent increase in the public debt - GDP ratio will redistribute welfare to the benefit of present generations and place a fiscal burden on future generations (Diamond (1965), Auerbach and Kotlikoff (1987)). In small open economy models, such a policy will in the end lead to an even higher permanent *foreign* debt as well as reduced welfare of all future generations, see Persson (1985). Future generations loose because the necessary trade surpluses crowd out consumption.[1]

This potential conflict of interest among present and future generations is of particular significance in countries like Norway, where the government owns a huge petroleum wealth in addition to net financial assets. We calculate the petroleum wealth as the present value of expected future net revenues from the petroleum sector. The significance of the petroleum wealth for intergenerational redistribution may be overlooked by policy makers because this wealth concept is not part of the definition of wealth in the National Accounts. Therefore, the conventional definitions of the central government's budget surplus and the current account surplus do not reflect changes in the petroleum wealth. A rough estimate of Norway's petroleum wealth in 1992 is 141 percent of GDP, of which about 80 percent is owned by the central government.

At some future date the oil and gas reserves will be exhausted. If the government does not build up stocks of other assets to compensate for vanishing petroleum wealth, the real net asset position of the government will deteriorate. This will, however, not be detected by the National Accounts or the public sector accounting system. An economic policy which fails to compensate for the government's declining petroleum wealth will reduce future generations' welfare in much the

[1] We assume that the real rate of interest is greater than the natural growth rate.

same way as increased public debt does.

The present paper illustrates this intergenerational conflict of interest by simulating an overlapping generations model calibrated to Norwegian data. Our model does not imply "Ricardian equivalence" (see Barro (1974)), but in contrast to pure life cycle models of saving, in which there are no intended bequests, we assume that parents derive utility from giving wealth to their children in the form of bequests. This is often referred to as the "joy-of-giving" bequest motive, see Blinder (1974) and Abel and Warshawsky (1988). We simulate the effects of gradually decreasing the government's wealth in the course of the next forty years as a result of vanishing petroleum wealth. The results indicate that the negative effects of such a policy on future generations' consumption are substantial.

In the next section we briefly discuss the calculation of Norway's petroleum wealth. Section 3 explains the main features of the computable overlapping generations model. The results of the simulations are presented in section 4. Section 5 summarizes the main findings and discusses policy implications. The appendix contains more details about the model and its calibration.

2. THE PETROLEUM WEALTH

Since the middle of the 1970s, the Norwegian petroleum sector has grown rapidly and is now crucial for the balance of payments and national income. In years with a high oil price such as 1984 and 1985, the petroleum sector contributed to 18 percent of nominal GDP and more than 35 percent of the value of total exports from Norway. Due to increased production since 1985, the petroleum sector still contributed to 16.3 percent of nominal GDP and 32.6 percent of the value of total exports in 1993. The rate of return has been significantly higher in the petroleum sector than elsewhere in the economy, generating a substantial average petroleum rent. This rent has been estimated to be 4.4 percent of nominal GDP in 1990. It was as large as 13.0 percent of GDP in 1984.[2] The size and variability of the petroleum rent highlights the importance of the petroleum wealth concept for fiscal policy analysis.

The production of oil was 2.3 million barrels per day in 1993 and is expected to increase further before a peak is reached in the late 1990s. Norway is now a larger oil producer than the U.K. According to the 1993 annual report from the Norwegian Petroleum Directorate, the stock of discovered oil reserves in the ground amounts to 20 years of production. The existing reserves of natural gas are expected to last for 115 years if the current, fairly modest rate of production is sustained. The production of natural gas is expected to increase substantially in the next 10-15 years, however. Together with Norway's huge hydroelectric power capacity, the existing oil and natural gas reserves will make Norway one of Europe's most important energy suppliers in many decades ahead. This will be the case whether Norway becomes a member of the European Union or not.[3]

The petroleum wealth estimate is calculated as the present value of expected future net revenues. Abstracting from uncertainty and assuming a given oil price path, field specific gas prices, field specific costs and given (not necessarily optimal) depletion trajectories, it is straightforward to calculate the discounted sum of the net expected cash flow.[4] In our small open economy framework, it is

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[2] Source: The Central Bureau of Statistics of Norway. The existence of a petroleum rent is due to economic resource scarcity as well as the cartel arrangement among the petroleum producing countries.

[3] It is not likely that the membership question will have any bearing on our petroleum wealth estimates or simulation results. For Norway, it is possible to fulfil the Maastricht requirement limiting the public sector deficit to 3 percent of GDP, and still redistribute from future generations to the generations presently alive, by consuming its petroleum wealth.

[4] This method neglects the possibility of choosing flexible strategies, i.e. different petroleum fields with different characteristics should start their exhaustion when the petroleum price at a future unknown date reaches a prescribed level. Our approach is consistent with the petroleum wealth calculations carried out by Aslaksen et al. (1990).

natural to adopt the world real interest rate as an exogenous discount rate. Our baseline simulation assumes a 4 percent real rate of return.

Directly through public ownership or indirectly through petroleum taxation, approximately 80 percent of the total petroleum wealth belongs to the government. Adopting a 4 percent real rate of interest and assuming a constant oil price equal to 120 Norwegian kroner (about $ 17.5) yield an estimate of the petroleum wealth of the Norwegian government equal to 869 billions Norwegian kroner.[5] This corresponds to about $32,000 per capita. The government's annual permanent income from this wealth is 35 billion kroner (about $ 5 billion). Clearly, because of the uncertainty associated with projections of the future price of oil, as well as other variables, our estimates of the petroleum wealth and the permanent income from it are very rough. We also note that the wealth estimate is very sensitive to the choice of a discount rate. Actually the volatility is about 14 percent (Thøgersen (1990)). If we adopt a 7 percent discount rate (following Aslaksen et al. (1990)), the estimate of the government petroleum wealth is reduced to 563 billion kroner.[6]

3. A COMPUTABLE OVERLAPPING GENERATIONS MODEL

The simulation model is a long-run overlapping generations model of a small open economy, see the Appendix. It is essentially a one good model. The exogenous real interest rate is 4 percent annually. In order to see how sensitive our results are to the choice of a discount rate, we also present calculations adopting discount rates equal to 2 and 7 percent.

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[5] The data underlying our calculations are provided by the Norwegian Ministry of Finance. The assumption of a constant oil price equal to 120 kroner is in accordance with recent oil price projections used by Norwegian authorities.

[6] The permanent income estimate is more roboust to changes in the rate of interest than the wealth estimate. A 7 percent discount rate yields an annual permanent income to the government of 39.4 billion kroner, which is only 12.6 percent higher than the permanent income estimate in the case of a 4 percent discount rate.

Assuming exogenous age-specific fertility and mortality rates, the model captures the ageing of the population due to low fertility rates after 1970, generating a transition to a stationary age distribution. The simulations are based on a projection of the aggregate fertility rate observed in the 1980s, which was below the reproduction level. In steady state, the population decreases by 0.30 percent per year.

One period is defined as 5 years. In each period a new generation is born. During the first 20 years of the life cycle, the children are supported by their parents. From period 5 to period 16 (the next 60 years), the representative individual follows an optimal life cycle plan. Hence, in every period there are 12 active overlapping generations. The model accounts for the wealth accumulation of each generation over time, as well as the flows of transfers in the form of social security benefits (including children allowance, disability pensions and old age pensions), bequests and capital income.

There are three domestic sectors: (i) private firms (ii) private households, and (iii) the government (including some industries regulated by the government). The firms produce a single all-purpose good which can be consumed, invested in physical capital (housing and production capital), or traded internationally. The technology is represented by a Cobb-Douglas production function with constant returns to scale. Inputs are physical capital and labor, with a labor share equal to 75.3 percent. We assume an annual growth rate of labor-augmenting technical progress equal to 0.66 percent. Assuming perfect competition, it follows that the capital-labor ratio as well as the real wage in each period can be derived from the first-order conditions and the exogenous real rate of interest. This feature makes the model much easier to solve numerically than models of closed economies, see for example Auerbach and Kotlikoff (1987).

The representative individual enters the labor market at the age of 20. The labor supply is inelastic. The total labor supply depends on the size of the age groups between 20 and 65 years, the exogenous age- and sex-specific labor force participation rates and average working hours. The individual plans 3 periods of retirement (between age 65 and 80). The optimal life cycle plan is calculated by maximizing an intertemporal, time separable utility function subject to a lifetime budget constraint. This constraint requires the present value of private consumption and terminal wealth to be equal to the present value of lifetime income, which is the sum of future after-tax labor income, social security transfers and received bequest. Gross taxes are proportional to wage income. Note that total private consumption is divided between the consumption of housing services and nondurable consumption in each period up till the age of 80. In addition, terminal wealth enters the utility function, i.e. the "joy-of-giving" bequest motive. The calibration involves an annual flow of bequest equal to 1 percent of GDP in the first period (see Gjersem (1992)). For simplicity, generations older than 80 years are assumed to consume their social security pension, and they do not accumulate wealth.

The government receives taxes to finance exogenous expenditures on goods and services as well as social security benefits on a pay-as-you-go basis. There are no tax distortions in the labor or capital markets. The government's wealth consists of physical capital, petroleum wealth and financial assets, all yielding the exogenous rate of return. In the present deterministic framework, what matters for welfare is total wealth, not its composition. The exogeneous time profile of the government's net asset position determines the tax requirement in each period. A fiscal policy which involves consumption of government wealth implies that current generations place a fiscal burden on future generations. If the government's wealth per efficiency unit of labor is constant over time and government spending on goods and services grows with the natural growth rate, the model will converge to a steady state. Since the natural growth rate is considerably lower than the interest rate, debt policy has significant effects on intergenerational distribution.

4. SIMULATION RESULTS

This section presents two scenarios. First we report a *baseline* simulation in which no wealth consumption takes place neither in the short nor the long run. Then we consider a *wealth consumption scenario* in which the government's petroleum wealth is consumed in the course of the next forty years, before a new steady state is approached. This leaves future generations with a lower national wealth and higher taxes than in the baseline case. Public expenditures on goods, services and transfers are identical in the two simulations, but taxes are different, see Figure 1. The wealth consumption scenario illustrates what may happen if the government reduces taxes instead of accumulating other assets to compensate for vanishing petroleum wealth during the next forty years. Such a policy is not unlikely, resulting for example from political pressure from special interest groups. In our model the tax cuts will boost current consumption at the expense of the consumption of future generations.

In the baseline simulation, the gross tax rate is not constant over time because of the effects of population ageing and the social security system. During the period from 1988 to 2038 the tax rates increase gradually, and thereafter they decrease marginally. When the baby-boomers start to retire from about 2012, social security transfers will begin to accelerate. This explains much of the baseline tax increases in Figure 1.[7]

In the wealth consumption simulation, taxes are lower than baseline up till 2013. Since all the government petroleum revenues are used to finance the tax cuts, no part of the petroleum wealth is transformed to other government assets. This implies a total deterioration of public wealth equal to 1134 billion 1988 kroner in 2028. In 2028 the public wealth consumption stops and taxes are raised in order to stabilize the new lower level of public wealth per efficiency unit of labor, see Figure 2. We assume that the loss of public wealth (per efficiency unit of labor) is permanent, i.e. the wealth consumption growth path approaches a steady state. After the tax cuts in 1993-2013, tax rates are increased considerably and from 2042 the tax rate is stabilized at a significantly higher level than the baseline tax rate.

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[7] The problems of financing the social security system in response to population ageing are adressed in Steigum (1993).

Figure 1 Gross tax rates

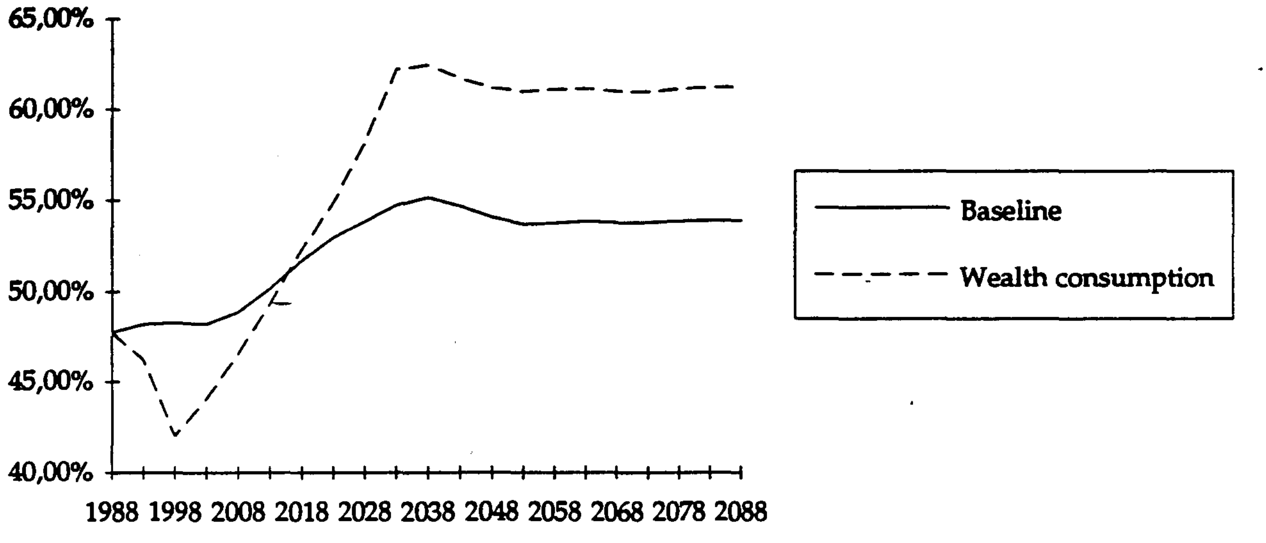
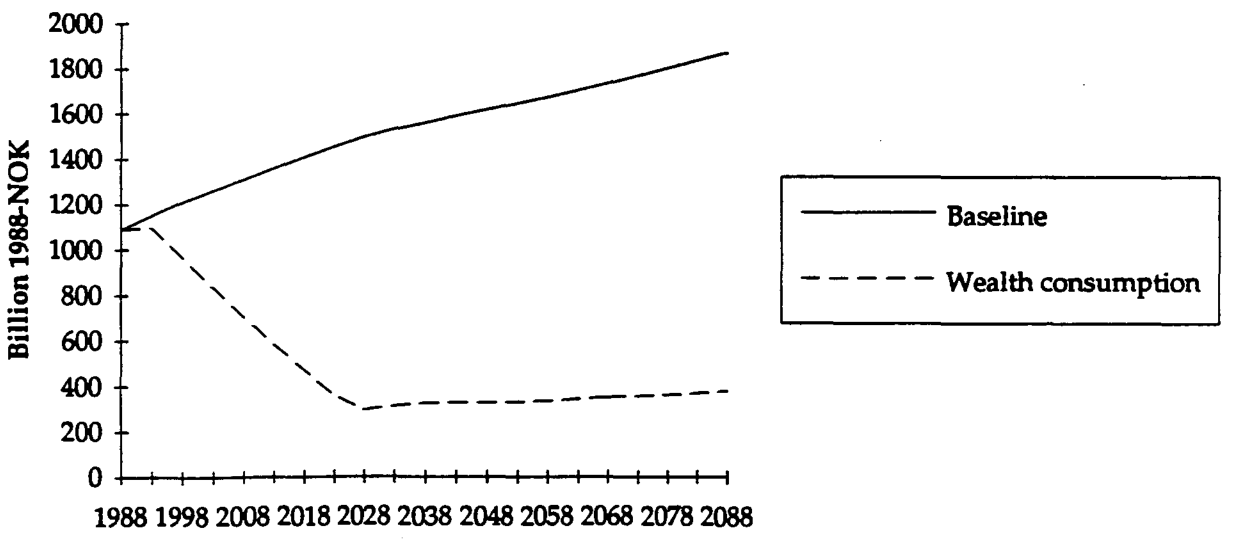


Figure 2 Net public financial assets incl. petroleum wealth



The intergenerational welfare effects of the wealth consumption policy are illustrated in Figure 3, which shows the changes in per capita consumption of successive generations when each are in age group 40-44 years. Since all generations have identical preferences and the real rate of interest is constant, the consumption of a representative consumer in any period is proportional to the present value of his lifetime income. Therefore, consumption in any age group can act as a welfare index, and our choice of age group 40-44 to represent each generation's consumption is arbitrary. Figure 3 shows that the generations who get tax cuts in 1993-2013 without being seriously hurt by the tax increases later, are those who benefit from the wealth consumption policy. In particular this is the case for those of age 40-44 years in the first periods. Young generations gain little and all generations younger than 10 years in 1988-92 (40 years in 2018-2022, see Figure 3) loose because of the future tax increases. Observe that the results also reflect that younger generations will receive larger bequests from older generations that gained from the policy.

In steady state, the consumption of all generations drops by 14 percent compared to the baseline simulation. Figure 3 reveals a remarkable lack of symmetry between the consumption gains of the winners and the consumption loss of the very young (and unborn) generations. This is because the real rate of interest is much greater than the natural rate of growth, generating substantial compounded interest effects over long time spans.

Figure 4 highlights the effects of the wealth consumption policy on aggregate private wealth. First, the tax cuts lead to increased accumulation of private wealth, because the generations who gain wish to save more in order to smooth consumption over time and leave larger bequests. Expectations of increased future taxes add to this effect on private saving. In the longer run, private wealth declines below the baseline wealth because lower welfare reduces life cycle savings and bequests.

Figure 5 illustrates the effect of the policy on the stock of foreign assets (incl. the

Figure 3 **Changes in consumption per capita relative to baseline, age group 40-44 years**

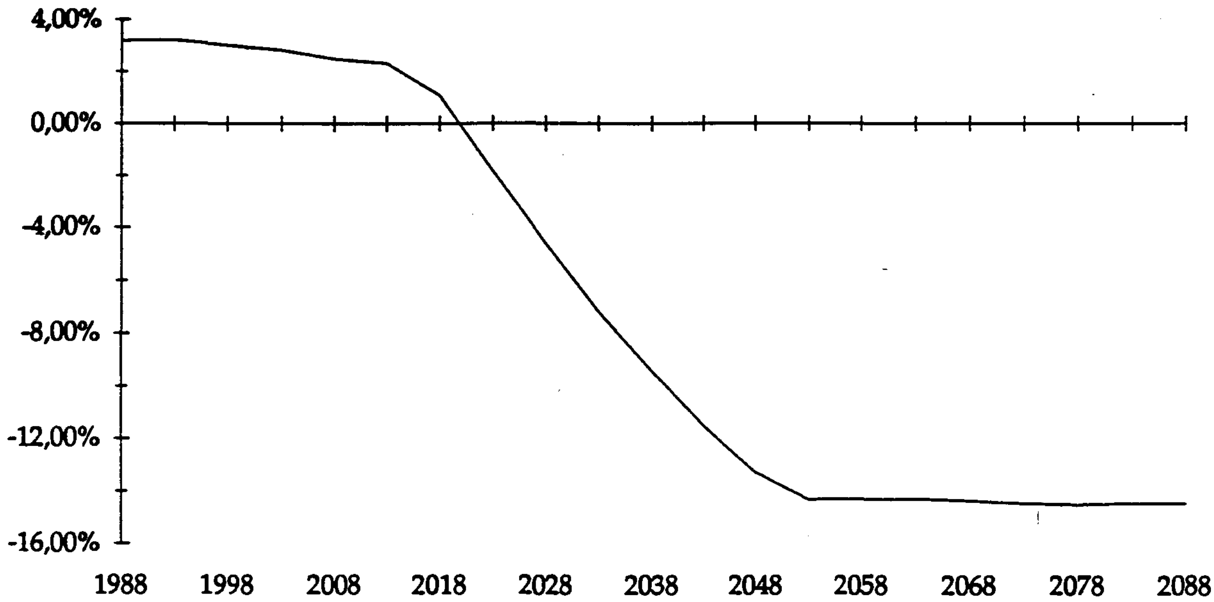


Figure 4 **Total private assets**

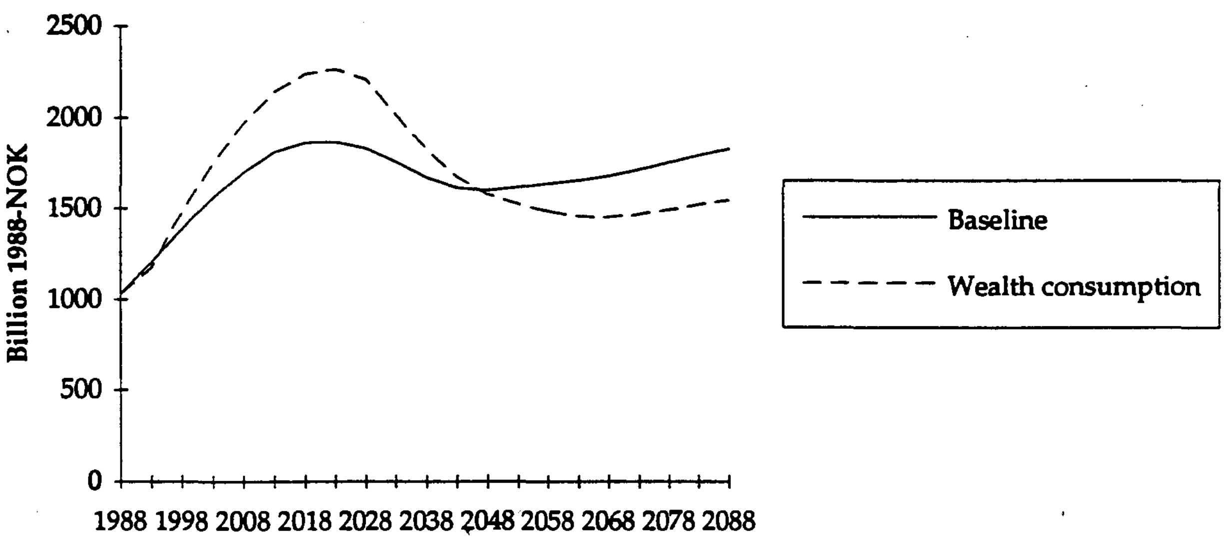
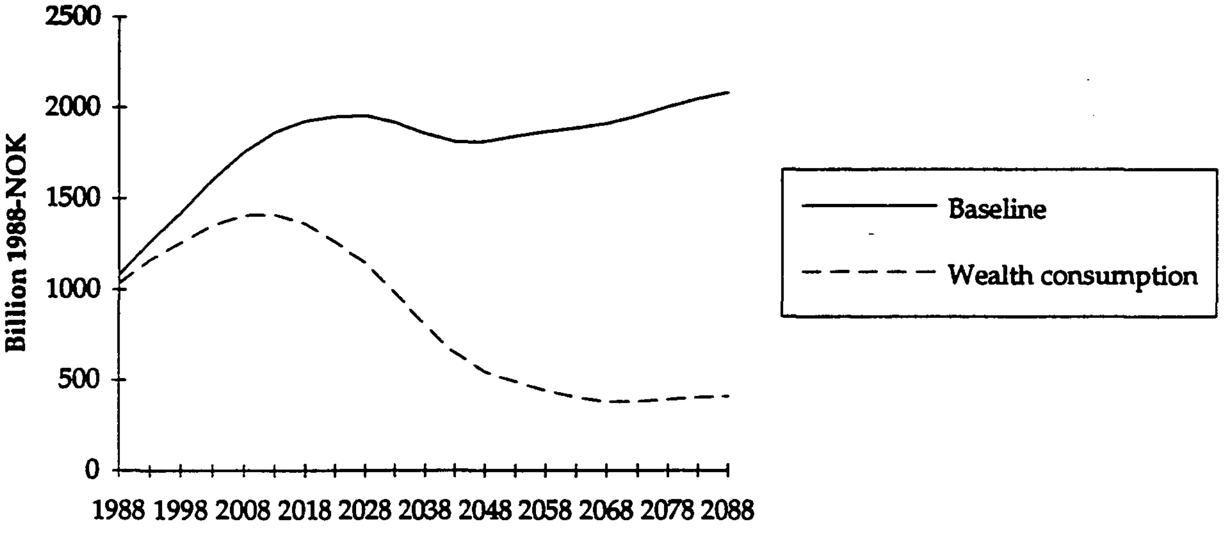


Figure 5 **Foreign assets incl. petroleum wealth**



petroleum wealth). During the years of tax reductions (1993-2013), increased private wealth counteracts the negative effects on the foreign asset position stemming from declining public wealth as well as from the increased demand for residential investment. This explains why the negative effects of the wealth consumption policy on foreign assets occur with a considerable time lag, compare Figure 2 and Figure 5.

It is natural to ask how sensitive our conclusions are to changes in the interest rate, keeping the rates of time preference and long-run growth constant. To examine this question, the simulation experiments above were repeated with real interest rates equal to 2 and 7 percent respectively. The corresponding petroleum wealth estimates were revised to 1247 and 563 billion kroner. The 2 percent rate implies a lower permanent income from the government petroleum wealth than the 4 percent case, and therefore taxes are somewhat higher. Intertemporal substitution yields a flatter consumption profile over the life cycle, generating less private wealth than previously. Opposite conclusions follow when the rate of interest is 7 percent.

A lower interest rate reduces the cost of a wealth consumption policy because more generations gain and the reduction in steady state consumption is smaller. This is illustrated in Figure 6 and 7, which show the consumption of successive generations when each are in age group 40-44 years for the 2 and 7 percent cases respectively, compare Figure 3. The eight first generations gain in the case of 2 percent interest rate, the six first generations gain in the 4 percent case and the five first generations gain if the rate of interest is 7 percent. In steady state consumption drops relative to baseline by approximately 7 percent in the 2 percent interest case, 14 percent in the 4 percent case and as much as 24 percent in the 7 percent case.

5. CONCLUSIONS

Due to the huge petroleum wealth owned by the Norwegian government, the choice of fiscal policy strategy for spending the petroleum revenues could have a

Figure 6 **Changes in consumption per capita relative to baseline, age group 40-44 years - 2 percent interest rate**

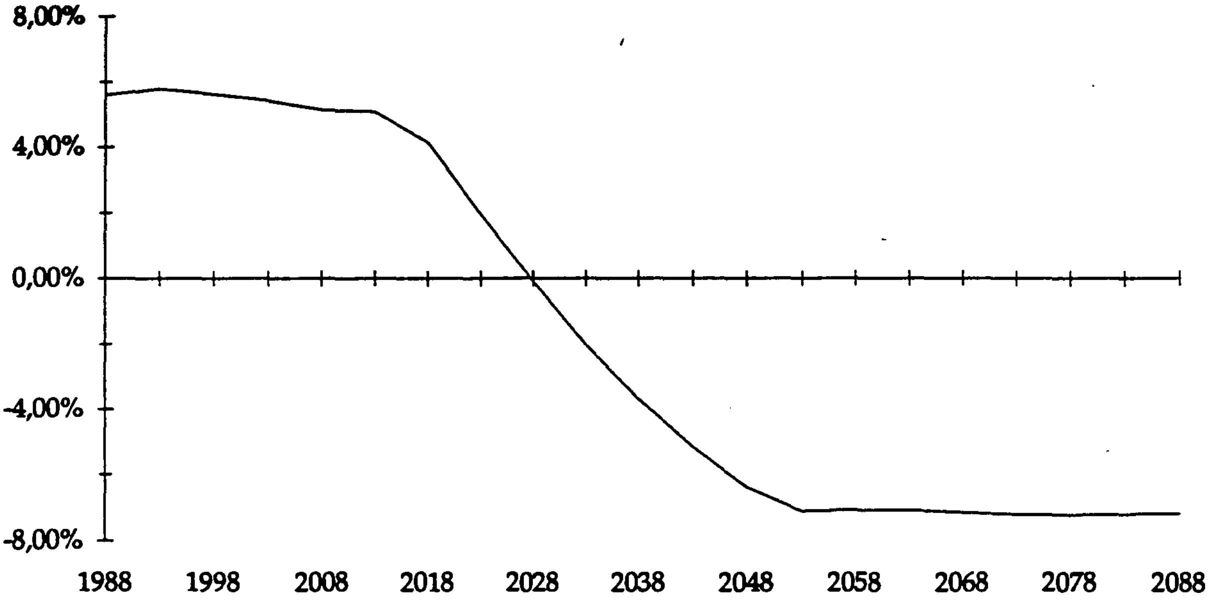
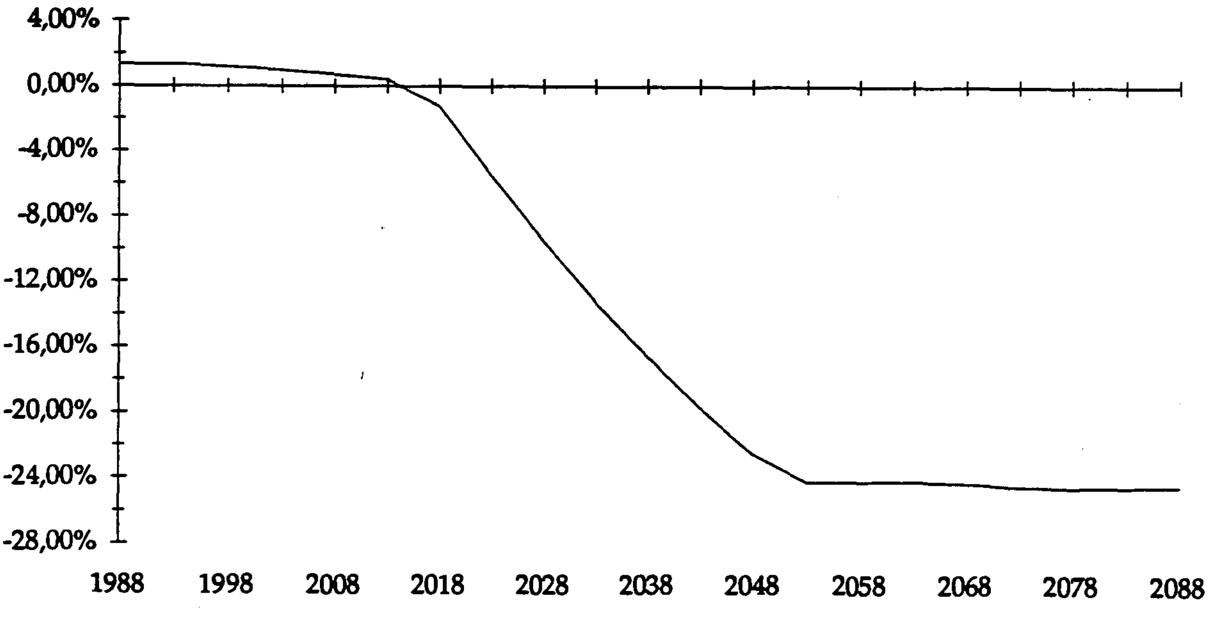


Figure 7 **Changes in consumption per capita relative to baseline, age group 40-44 years - 7 percent interest rate**



significant impact on the welfare of future generations. To address this question, we used a computable overlapping generations model to simulate two different scenarios. The model captures the ageing of the population due to low fertility rates after 1970, and takes into account the effects of social security transfers and bequests on consumption and saving, assuming a "joy-of-giving" bequest motive.

In the first baseline scenario, the petroleum wealth is transformed into foreign assets before a steady state growth path is approached in the very long run. In this case all generations will benefit from the initial petroleum wealth. The second scenario assumes that the government's petroleum wealth is consumed over a period of 40 years, leaving future generations with a permanent lower stock of public wealth and higher taxes. The intergenerational welfare effects turn out to be substantial, particularly for the very young and all unborn generations. In steady state, per capita consumption is 14 percent lower than in the baseline case, assuming a gap between the annual real rate of interest and the natural rate of growth of about 3.5 percentage points. The effects are somewhat sensitive to the size of this gap. If the real rate of interest is 2 percent, the reduction in steady state consumption (per capita) is 7 percent, and in the case of a 7 percent real rate of discount, the corresponding reduction in consumption is as large as 24 percent.

APPENDIX

The simulation model

Production

Private output (excluding the housing sector) is generated by a constant returns to scale Cobb-Douglas production function:

$$(1) \qquad X_t = (A_t L_t)^{\alpha} K_t^{1-\alpha}.$$

Here X_t is the contribution to GDP in period t, A_tL_t is the effective labor supply, L_t is labor supply measured in natural units, K_t is capital and α is the constant labor share. L_t grows with the rate n and A_t with the rate λ. The marginal product of capital is equal to the rental price, $r+\delta^p$, where r is the constant real interest rate and δ^p is the rate of depreciation of private real capital. It follows that the capital intensity $k_t \equiv K_t/L_t$ is determined by the rental price and the parameters of the production function:

$$(2) \qquad k_t = \left(A_t^{\alpha}(1-\alpha)(r+\delta^p)^{-1}\right)^{1/\alpha}.$$

Since L_t is given exogenously, the optimal K_t is derived from (2), and gross investment is given by

$$(3) \qquad I_t = K_t - K_{t-1} + \delta^p K_t.$$

The real product wage (w_t^*) is equal to the marginal product of labor, i.e.

$$(4) \qquad w_t^* = \alpha A_t^{\alpha} k_t^{1-\alpha}.$$

The government's demands for labor and physical capital are exogenous.

Household behavior

The model consists of 12 active overlapping generations. We assume that the four youngest and the four oldest generations are supported by their parents and the government respectively. The demographic development is given by age-specific fertility rates and age- and sex-specific mortality rates. The generations of age 20-40 become parents and for simplicity no one dies before the age 45.

Consider a representative grown-up individual entering the first period of his life cycle (age 20-25) at the beginning of period t. His utility function is a time separable CES function with an intertemporal elasticity of substitution equal to $1/\gamma$, $\gamma>0$,

$$(5) \qquad U_{1,t} = \frac{1}{1-\gamma}\left(\sum_{j=1}^{12} \beta_{j,t+j-1} C_{j,t+j-1}^{1-\gamma} + \beta_{13,t+12} B_{13,t+12}^{1-\gamma}\right)^{\frac{1}{(1-\gamma)}}.$$

Here $C_{j,t+j-1}$ is consumption in age period j ($j=1,...,12$) at time $t+j$ and $B_{13,t+12}$ is bequest to the offspring. The weights $\beta_{j,t+j-1}$ are defined by

$$(6) \qquad \beta_{j,t+j-1} = \left(N_{j,t+j-1} + \sum_{s} \Theta_s N_{s,t+j-1}\right)(1-\rho)^{j-1},$$

where $N_{j,t+j-1}$ is the number of adults in generation j in period $t+j-1$, $N_{s,t+j-1}$ is the number of children in age-group s ($s=-3,-2,-1,0$) in period $t+j-1$, Θ_s captures the expenditures related to the resposibility for children and ρ is the pure rate of time preference. The weight $\beta_{13,t+12}$ is

$$(7) \qquad \beta_{13,t+12} = \eta N_{13,t+12}(1-\rho)^{12},$$

where η is a parameter reflecting the strength of the "joy-of-giving" bequest motive.

Total consumption is a CES composite good consisting of the consumption of housing services (h) and nondurable consumption (c). Assuming a constant rate of interest, the intertemporal budget constraint is given by

$$(8) \qquad \sum_{j=1}^{12} (1-r)^{j-1} P \cdot C_{j,t+j-1} + (1-r)^{12} B_{13,t+12} = V_{1,t},$$

where P is the constant price index of the composite good, r is the constant real after tax interest rate and $V_{1,t}$ is the present value of all future after tax wage income, received bequest and social security transfers. $V_{1,t}$ is defined as

$$(9) \qquad V_{1,t} = \sum_{j=1}^{12} (1-r)^{j-1}\left(w_{j,t+j-1} L_{j,t+j-1} + TR_{j,t+j-1} + B_{j,t+j-1}\right).$$

Here $TR_{j,t+j-1}$ is the social security contributions, w_{t+j-1} is the real after tax wage rate,

$L_{j,t+j-1}$ is the labor supply and $B_{j,t+j-1}$ is bequest received from previous generations.

Maximization of (5) subject to (8) gives standard demand functions for $C_{j,t+j-1}$ and $B_{13,t+12}$, $j=1,...,12$. The corresponding demands for nondurables and housing consumption are

$$(10) \qquad c_{j,t+j-1} = (\alpha^c/P)^\sigma C_{j,t+j-1},$$

and

$$(11) \qquad h_{j,t+j-1} = [\alpha^h(r+\delta^h)/P]^\sigma C_{j,t+j-1}.$$

Here δ^h is the rate of depreciation for housing wealth, σ is the atemporal elasticity of substitution between c and h, and α^c and α^h are the corresponding weights.

National wealth

National wealth (excluding human capital) is given by:

$$(12) \qquad NW_t = K_t + K^g_t + H_t + F_t,$$

where K^g_t is the public capital stock, H_t is private housing wealth, F_t is the sum of foreign assets and the exogenous petroleum wealth. In steady state all the components in (16) are constant per efficiency unit of labor.

Calibration

The model is calibrated to the Norwegian economy mainly by using data from the National Accounts. Both private and government wealth and the foreign debt for 1988 are reproduced in the model's initial period. Some key parameter values are given in table A-1.

Calibration of the initial allocation of wealth between the generations gave a rate of time preference equal to 0.20 percent on an annual basis. The η parameter reflecting the bequest motive is calibrated such that the bequest in the model's initial period is equal to 1 percent of GDP in 1988 (Gjersem, 1992). Assuming a partial recovery of the fertility rate from the low level of the 1980s, the long-run population growth rate is -0.30. The 0.5 percent values of the intertemporal elasticity of substitution ($1/\gamma$) and the atemporal elasticity of substitution of the consumption bundle (σ) as well as the 0.66 percent rate of labor-augmenting technical progress are broadly consistent with existing empirical evidence. For more details about calibration and parameter values, see Steffensen and Steigum (1990).

Real rate of interest	4	(annual)
Rate of time preference	0.20	(annual)
Intertemporal elasticity of substitution ($1/\gamma$)	0.5	
Atemporal elasticity of substitution (σ)	0.5	
Rate of technical progress (labor-augmenting)	0.66	(annual)
Long-run population growth rate	-0.30	(annual)

Table A-1. Some key parameters, percent.

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ESSAY 5

FISCAL POLICY, STRUCTURAL ADJUSTMENT AND INTERGENERATIONAL WELFARE*

ABSTRACT

This paper considers a dynamic dependent economy model extended to incorporate finite horizons of the households and structural adjustment costs in production. We analyze the effects of an unexpected drop in the government wealth interpreted as the result of a depreciation of the government petroleum revenues. If the tax level increases instantaneously in order to stabilize government wealth, consumption and human wealth undershoot their new stationary equilibrium values. The present generations experience both the permanent tax increase and the entire burden of the adjustment costs. Succeeding generations increase their consumption level since they face gradually less adjustment costs and at the same time benefit from past adjustments. If the tax increase is delayed, the undeshooting tendency is weakened. The adjustment costs are distributed more evenly between the generations but the long run stationary consumption level is lowered due to a higher tax burden.

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1. INTRODUCTION

Many economies endowed with petroleum or other natural resources have experienced the "Dutch disease" phenomenon. This refers to the observation that a domestic resource discovery triggers wealth effects which - among other things - cause a decline of the traditional tradeable goods sector, see the surveys of Corden and Neary (1982) and Corden (1984). The problematic part of this development appears when the "re-entry" problem arises, i.e. the need for a return of a larger tradeable goods sector in response to a petroleum wealth depreciation following a persistent negative price shock or the exhaustion of the reserves, see van Wijnbergen (1985).

This paper is devoted to the re-entry problem, and we analyze structural aspects of an unexpected drop in the government petroleum wealth in a dependent economy model (see Dornbush (1980)) where the agents have finite horizons.[1] The drop in the government petroleum wealth leads to a fiscal restraint which triggers structural adjustments. Labor is the only factor of production, and we assume the presence of adjustment costs related to intersectoral transfer of labor. This implies that the optimal structural adjustment process is gradual and time-consuming. Contrary to the previous literature in this field, we highlight how the timing of the fiscal restraint and the adjustment process influence the consumption decisions and welfare of different generations.[2] The analysis is motivated by present problems in some petroleum economies. Still, it is not linked exclusively to natural resource economies and it is relevant for all open economies which face adjustment problems after negative wealth shocks or periods of extensive debt accumulation.

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[1] The assumption of a government petroleum wealth captures the fact that in most petroleum economies the government receives the main parts of the petroleum revenues through direct ownership of the resources or indirectly through taxation. For example in Norway, approximately 80% of the petroleum revenues are collected by the government.

[2] The previous literature analyzing dynamic versions of the dependent economy model includes Broch and Turnovsky (1993), van Wincoop (1993), Gavin (1990), Steigum (1992), Buiter (1988) and Dornbusch (1983).

This study is closely related to Steigum (1992) and Buiter (1988). They both consider dynamic versions of the dependent economy model and abstract from capital formation. In Steigum's model there are adjustment costs, i.e. training costs, involved in the process of transfering workers between the non-traded and traded goods sector. Intergenerational issues are not dealt with, however. The optimal structural adjustment path to a negative wealth shock is determined by an utility maximizing infinitely lived representative agent. In Buiter's model the consumption decisions of the households are modelled through a version of the Blanchard (1985) overlapping generations model. On the other hand the production side of his model is rather crude and there are no intersectoral adjustment costs. In our model we make an attempt to combine the most interesting features of the models of Steigum and Buiter. In order to incorporate an overlapping generations structure in the model of Steigum, we model household behaviour along essentially the same lines as Buiter.

The next section presents our model. Then we turn to the analysis of an unexpected drop in the petroleum wealth which lowers government wealth and leads to a fiscal restraint. We start out by looking at the effects on the stationary equilibrium in section 3. Section 4 deals with the adjustment process when the drop in the petroleum wealth is followed instantaneously by a tax increase which stabilizes government wealth at a new and lower level. In section 5 we consider how the postponement of the tax increase matters for different generations. Section 6 offers some concluding remarks.

2. THE MODEL

We consider a small open economy with two production sectors, one T-sector producing traded goods (i.e. traditional manufacturing goods) and one N-sector producing non-traded goods. The firms in both production sectors are privately owned. We assume that the price of traded goods is constant and normalized to one. The real interest rate in terms of tradeables, r, is constant and given in a perfect international credit market. There is also a petroleum sector exporting oil and natural gas. The net petroleum export revenues are collected by the government. No domestic production factors are employed in the extraction activities. This means that we focus exclusively on the "spending effects" of the petroleum sector (see for example Corden (1984)).

The modelling of the age and population structure follows Blanchard (1985). Time is continuous and each individual, independent of age, faces a constant instantaneous probability of death, $\pi \geq 0$. Therefore expected remaining lifetime for all individuals at a point of time is π^{-1}. It follows that in the limit, as π goes to zero, the horizon of the individuals goes to infinity. A new cohort is born at each instant of time and its size (at birth) is normalized to π. Each cohort is so large that the fraction which dies at each instant is also π. Under these assumptions the size of the entire population is constant and equal to *1*.

2.1. The households

We consider a representative individual born at time s. At time t ($t \geq s$) he maximizes expected utility which, assuming logarithmic instantaneous utility, is given by

$$(1a) \qquad E_t[u(s,t)] = E_t \int_t^{\infty} \log\left(c_T(s,z)^a c_N(s,z)^{1-a}\right) e^{-\theta(z-t)} \, dz \, .$$

Here the composite consumption good is a Cobb-Douglas function of consumption of traded goods ($c_T(t)$) and non-traded goods ($c_N(t)$), the corresponding expenditure shares are a and $(1-a)$ $(0<a<1)$, θ is the time preference rate and E_t denotes expectation conditional on time t information. Since the only source of uncertainty is the length of the lifetime, (1a) can equivalently be written

$$(1b) \qquad E_t[u(s,t)] = \int_t^{\infty} \log\left(c_T(s,z)^a c_N(s,z)^{1-a}\right) e^{-(\pi+\theta)(z-t)} \, dz \, ,$$

and we see that $\pi > 0$ raises the effective utility discount rate above θ.

The individual supplies one unit of labor inelastically at any point of time. His income before tax in terms of tradeables at time t, $y(s,t)$, consists of labor income and a share of the profit from the privately owned firms. We assume that $y(s,t)$ as well as the time t lump-sum tax (in terms of tradeables), $\tau(s,t)$, are independent of age. Hence, $y(s,t)=y(t)$, $\tau(s,t)=\tau(t)$ and the time t net income of the representative individual in any generation is $y(t)-\tau(t)$. Since each individual faces a risk of death while there is no aggregate uncertainty, there is scope for life insurance. Assuming that the individuals contract with insurance companies in a perfectly competetive insurance market, they agree to remit their non-human wealth, $v(s,t)$, upon death in exchange for a premium of $\pi v(s,t)$ per unit of time. Accordingly, there are no bequests.

The dynamic budget constraint of the representative individual is

$$\text{(2)} \qquad \frac{dv(s,t)}{dt} = (r+\pi)v(s,t) + y(t) - \tau(t) - c(s,t),$$

where c is total consumption in terms of tradeables. It follows that

$$\text{(3)} \qquad c(s,t) \equiv c_T(s,t) + p_N(t)c_N(s,t),$$

where $p_N(t)$ is the real exchange rate, the relative price of non-traded goods. When we assume that the non-ponzi game condition is satisfied,

$$\text{(4)} \qquad \lim_{z\to\infty} v(s,z)e^{-(r+\pi)(z-t)} = 0,$$

integration of equation (2) gives the intertemporal budget constraint

$$\text{(5)} \qquad \int_t^\infty c(s,z)e^{-(r+\pi)(z-t)}dz = v(s,t) + h(t).$$

Here h(t) is human wealth (which is independent of age given our assumptions),[3]

[3] Note that $h(t)$ includes shares of future profits from private firms, i.e. the term human wealth is slightly extended compared to the traditional definition.

(6) $$h(t) = \int_t^{\infty} [y(z) - \tau(z)] e^{-(r+\pi)(z-t)} dz.$$

The maximization of (1b) subject to (5) yields the solution

(7) $$c(s,t) = (\theta+\pi)[v(s,t) + h(t)],$$

and we have $c_T(s,t)=ac(s,t)$ and $c_N(s,t)=[(1-a)/p_N(t)]c(s,t)$. The consumption of the representative individual is a linear function of his wealth. Due to logarithmic utility the propensity to consume, $(\theta+\pi)$, is independent of r. We also obtain

(8) $$\frac{dc(s,t)}{dt} = (r-\theta)c(s,t).$$

The slope of the consumption path of the individual is determined by the sign of $(r-\theta)$.

Integrating over all generations and dropping the time index wherever it is not confusing yields aggregate consumption as

(9) $$C = (\pi+\theta)[H + V],$$

where we use capital letters to denote aggregate variables.[4] Of course, $C_T=aC$ and $C_N=[(1-a)/p_N]C$. Further, it follows (when T denotes the aggregate lump-sum tax) that

(10) $$\frac{dV}{dt} = rV + [Y - T] - C,$$

[4] If $x(s,t)$ is an individual variable, the corresponding aggregate variable is $X(t)=\int_{-\infty}^{t} x(s,t)\pi e^{\pi(s-t)}ds$. Here $\pi e^{\pi(s-t)}$ is the size of generation s at time t.

(11) $$H(t) = \int_t^{\infty} [Y(z) - T(z)] e^{-(r+\pi)(z-t)} dz,$$

and

(12) $$\frac{dH}{dt} = (r+\pi)H - [Y - T].$$

Since the size of the population is constant and equal to one, we may note that $Y=y$, $T=\tau$ and $H=h$. We assume that $Y(t)-T(t)>0$ for all t.

Using (9), (10) and (12) we obtain

(13) $$\frac{dC}{dt} = (r-\theta)C - \pi(\pi+\theta)V.$$

If $\pi>0$, the slope of the aggregate consumption path may - contrary to the slope of the individual consumption path (see (8)) - be non-zero even though $r=\theta$. In the infinite horizon case of $\pi=0$, the sign of dC/dt is unambiguously determined by the sign of $(r-\theta)$.

2.2. The government

The government collects the lump-sum taxes, T, and the net export revenues from the petroleum sector (in terms of tradeables), R. We assume a given extraction path and no uncertainty in prices and costs. Then, the government petroleum wealth is given by

(14) $$PW(t) = \int_t^{t_E} R(z) e^{-r(z-t)} dz.$$

Here t_E is the time of exhaustion. Total government wealth is

(15) $$\Omega = PW + B,$$

where B is government financial wealth. Since PW is given with certainty, what matters is the size of Ω, not its composition. If the budget policy ensures that $\Omega(t)$ is constant, the given extraction path determines changes in PW which are exactly offset by opposite changes in B (i.e. the exhaustion of the resources implies a corresponding accumulation of a financial petroleum fund).

Government consumption in terms of tradeables, G, is allocated between tradeables (G_T) and non-tradeables (G_N). We assume corresponding constant expenditure shares equal to b and $(1-b)$ $(0<b<1)$. Hence,

$$(16) \qquad G \equiv G_T + p_N G_N,$$

and $G_T=bG$ and $G_N=[(1-b)/p_N]G$. We assume that government consumption does not affect the marginal utility of private consumption.

The dynamic budget constraint of the government is

$$(17) \qquad \frac{d\Omega}{dt} = r\Omega + T - G.$$

Imposing the transversality condition $lim_{z\to\infty}\Omega(z)e^{-r(z-t)}=0$ yields the intertemporal budget constraint

$$(18) \qquad \Omega(t) = \int_t^{\infty}[G(z) - T(z)]e^{-r(z-t)}dz.$$

2.3. Production

In each production sector i $(i=T,N)$ there are many identical small firms which act as price takers in both the labor market and the product markets. Aggregate production in sector i at time t is given by the production function $Q_i(t)=F_i[X_i(t)]$ where $F_i'>0$, $F_i''<0$ and $X_i(t)$ is the effective labor force in the sector. Following Steigum (1984, 1992), there are training costs involved in the process of transfering labor between the sectors. Since this paper focuses on the transfer of labor to the T-sector, we model training costs in this sector only. (The modelling of training costs in both sectors is straightforward, however.) We also assume that all new workers must be trained before they enter the T-sector. It follows that

$$(19) \qquad X_N = 1 - L_T,$$

and

$$(20) \qquad X_T = L_T - I,$$

where L_T is the total work force in the T-sector and I is the number of "instructors" allocated to train workers entering the T-sector. We assume that knowledge is firm specific. As explained in more detail by Steigum (1984), this implies that the firms train new workers without charge and no wage differential arises between the sectors.

The training technology is given by

$$(21) \qquad \frac{dL_T}{dt} = \frac{I}{\alpha} - \pi L_T,$$

where the parameter $\alpha>0$ measures the number of instructors needed to educate one new worker in the T-sector per unit of time. We note that the case of $I=0$ implies $dL_T/dt<0$ since a fraction of the work force dies at each instant.

The firms maximize the wealth of the shareholders (i.e. the individuals). Since all individuals at one point of time receive the same labor income and identical shares of profit from the firms ($y(s,t)=y(t)$), this is equivalent to the maximization of human wealth before tax (see (11)). Hence, the development of the production sectors is determined by the maximization of

$$(22) \qquad \Pi(t) = \int_t^{\infty} Y(z) e^{-(r+\pi)(z-t)} dz,$$

where

$$(23) \qquad Y = F_T[L_T-I] + p_N F_N[1-L_T].$$

The maximization is subject to (21) and $L_T(0)=L_T^0$ as well as the non-negativity constraints $I(t)\geq 0$, $X_T(t)\geq 0$ and $X_N(t)\geq 0$. Invoking the Inada conditions $F_i(0)=0$,

$F_i'(0)=\infty$ and $F_i'(\infty)=0$, implies that the last two constraints never bind. As our analysis will demonstrate, we have $dL_T/dt \geq 0$ which implies that $I(t)>0$ when $\pi>0$. Therefore, $\pi>0$ ensures an inner solution.

In order to solve this dynamic optimization problem we define L_T as the state variable and I as the control variable. The current-value Hamiltonian is

$$(24) \qquad \Lambda = F_T[L_T-I] + p_N F_N[1-L_T] + \lambda\left(\frac{I}{\alpha} - \pi L_T\right),$$

where $\lambda(t)$ is the costate variable associated with (21). This leads to the following necessary conditions for an optimum:

$$(25) \qquad -F_T'[L_T-I] + \frac{\lambda}{\alpha} = 0,$$

$$(26) \qquad \frac{d\lambda}{dt} = -F_T'[L_T-I] + p_N F_N'[1-L_T] + \lambda[r+2\pi].$$

From (25) we derive

$$(27) \qquad \lambda = \alpha F_T'[L_T-I],$$

and $\lambda(t)$ is interpreted as the marginal cost of training.

Using (26) and (27), we obtain

$$(28) \qquad \frac{d\lambda}{dt} = -[1-\alpha(r+2\pi)]F_T' + p_N(t)F_N'.$$

We assume that $[1-\alpha(r+2\pi)]>0$, otherwise no transfer of labor to the T-sector will take place since the gain from a transfer of one unit of labor is always smaller than the rental training cost $\alpha(r+2\pi)F_T'$.[5] Integration of (28) implies

[5] The rental training cost is $\alpha(r+2\pi)F_T'$ where the term in parenthesis is the relevant discount rate plus π. Since the relevant discount rate of the owners of the firms (i.e. the households) is $(r+\pi)$, this term is $r+2\pi$.

(29) $$\lambda(t) = \int_t^{\infty}[(1-\alpha\pi)F_T' - p_N(z)F_N']e^{-(r+\pi)(z-t)}dz,$$

i.e. the marginal cost of training at any point of time should be equal to the present value of the gains from the transfer of the marginal worker into the T-sector.

2.4. Momentary equilibrium in the N-sector

The relative price of non-traded goods, p_N, adjusts instantaneously to equate supply and demand of non-tradeables. There are no inventories. Thus, the market clearing condition is

(30*a*) $$C_N + G_N = Q_N.$$

This equation can be rewritten as

(30*b*) $$(1-a)C + (1-b)G = p_N F_N[1-L_T],$$

and we may solve for p_N, $p_N=p_N(C,G,L_T)$. From (30b) it is easy to verify that $\partial p_N/\partial C=(1-a)/F_N>0$, $\partial p_N/\partial G=(1-b)/F_N>0$ and $\partial p_N/\partial L_T=(p_N F_N')/F_N>0$.

2.5. National wealth and foreign assets

The non-human national wealth is

(31) $$NW = \Omega + V = PW + A,$$

where A is foreign financial assets, $A=B+V$. Using (10) and noting that $dB/dt=rB+R+T-G$, we obtain the current account surplus as

(32) $$\begin{aligned}\frac{dA}{dt} &= rA + Y + R - [C + G] \\ &= rA + Q_T + R - [C_T + G_T].\end{aligned}$$

Since $dPW/dt=rPW-R$, we also have

$$(33)\qquad \frac{dNW}{dt} = rNW + Y - [C + G] = rNW + Q_T - [C_T + G_T].$$

2.6. Dynamics and stability

Our model defines the following dynamic system in C, V, L_T and λ:

$$(13)\qquad \frac{dC}{dt} = (r-\theta)C - \pi(\pi+\theta)V,$$

$$(10b)\qquad \frac{dV}{dt} = rV + [Y(C,L_T,\lambda) - T] - C,$$

$$(21b)\qquad \frac{dL_T}{dt} = \left(\frac{1}{\alpha} - \pi\right)L_T - \frac{1}{\alpha}X_T(\lambda),$$

$$(26b)\qquad \frac{d\lambda}{dt} = -F_T'[X_T(\lambda)] + p_N(C,L_T)F_N'[1-L_T] + \lambda[r+2\pi].$$

In deriving (21b) and (26b), we have used the fact that (25) implies that X_T $(=L_T-I)$ is a function of λ, $X_T=X_T(\lambda)$. We also note that we may write (see (10b)) $Y\equiv Y(C,L_T,\lambda)= F_T[X_T(\lambda)]+p_N(C,L_T)F_N[1-L_T]$.

In the appendix we have linearized the dynamic system and discussed the conditions for local saddle path stability. Since there are two predetermined variables (V and L_T) and two "jump-variables" (C and λ), corresponding numbers of positive (unstable) and negative (stable) eigenvalues imply saddle path stability. Our linearized system defines a fourth-degree polynomial characteristic equation, and it is difficult to solve explicitly for the eigenvalues. However, in the appendix we derive a necessary condition which is satisfied when $r(r-\theta)<a\pi(\pi+\theta)$, i.e. $r\leq\theta$ or r not too much larger than θ. Throughout the rest of this paper we assume $r(r-\theta)<a\pi(\pi+\theta)$.

3. STATIONARY EQUILIBRIUM

It follows from (17) that the stationary tax is given by

$$(34) \qquad T = G - r\Omega.$$

Obviously T varies inversly with Ω and an unexpected drop in the petroleum wealth increases T. In the rest of the paper we assume that G is exogenous and constant.

Turning to the production side of the model, stationarity requires that $I=\alpha\pi L_T$ (see (21)). Since a fraction of the work force dies at each instant and new workers entering the T-sector must be trained, there is a constant stock of instructors who at each instant trains a constant fraction of the newborn generation. From (28) we obtain

$$(35) \qquad F_T'[(1-\alpha\pi)L_T] = p_N F_N'[1-L_T] + \alpha(r+2\pi)F_T'[(1-\alpha\pi)L_T].$$

In stationary equilibrium the values of L_T and p_N must satisfy the condition that the gain from the marginal worker in the T-sector (LHS of (35)) should be equal to the marginal cost which is the value of output forgone in the N-sector plus the rental training cost (RHS of (35)). From (35) it is straightforward to verify that the stationary values of L_T and p_N vary inversely.

The stationary income before tax is (from (23))

$$(36) \qquad Y = F_T[(1-\alpha\pi)L_T] + p_N F_N[1-L_T].$$

Looking at the households, (10) and (12) imply

$$(37) \qquad V = \frac{1}{r}[C - (Y - T)],$$

and

$$H = \frac{1}{r+\pi}(Y - T), \tag{38}$$

in a stationary equilibrium. Combining (37) and (13) and assuming $\pi>0$, we obtain the stationary level of consumption as

$$C = \frac{1}{1 + \frac{r(\theta-r)}{\pi(\theta+\pi)}}(Y - T). \tag{39}$$

Our assumption $r(r-\theta)<a\pi(\theta+\pi)$ (see section 2.6) implies a strictly positive denominator. It follows from (39) that we may obtain a stationary equilibrium even though $r\neq\theta$. In the case of $r=\theta$, (37) and (39) imply that $C=Y-T$ and $V=0$. In the extreme case of $\pi=0$, we must have $r=\theta$ in order to obtain a stationary equilibrium, see (13).

Noting that (37) and (39) imply

$$V = \frac{(Y - T)}{r}\left(\frac{1}{1 + \frac{r(\theta-r)}{\pi(\theta+\pi)}} - 1\right), \tag{37b}$$

we see that the sign of V is equal to the sign of $(r-\theta)$.

Stationary equilibrium in the N-sector requires (see (30b))

$$(1-a)C + (1-b)G = p_N F_N[1-L_T]. \tag{40}$$

From (33), we obtain

$$rNW = C + G - Y = C_T + G_T - Q_T. \tag{41}$$

The stationary net import except petroleum revenues is equal to the return on the non-human national wealth.

The stationary equilibrium is characterized by the equations (34)-(41). When G is exogenous, we obtain one equilibrium solution for the endogenous variables p_N, Y,

C, V, H, NW, L_T and T for each possible value of Ω.

In order to study the effects on the stationary equilibrium of a drop in the petroleum wealth, we calculate $dL_T/d\Omega$. Using (34), (36) and (39), we rewrite (40) as

$$\text{(42)} \qquad \frac{1-a}{1+\gamma}\Big(F_T[(1-\alpha\pi)L_T] + p_N F_N[1-L_T] - G + r\Omega\Big) + (1-b)G - p_N F_N[1-L_T] = 0,$$

where $\gamma=[r(\theta-r)]/[\pi(\theta+\pi)]$. From (42), we obtain

$$\text{(43)} \qquad \frac{dL_T}{d\Omega} = \frac{-r\left(\dfrac{1-a}{1+\gamma}\right)}{\left(\dfrac{1-a}{1+\gamma}\alpha(r+\pi) + [1-\alpha(r+2\pi)]\right)F_T' + \left(\dfrac{1-a}{1+\gamma} - 1\right)F_N\dfrac{dp_N}{dL_T}}.$$

In deriving this equation, we have used that (35) implies $p_N F_N'=[1-\alpha(r+2\pi)]F_T'$. It is easy to verify that the stability condition $r(r-\theta)<a\pi(\pi+\theta)$ ensures that $0<(1-a)/(1+\gamma)\leq 1$. Since $dp_N/dL_T<0$ and $[1-\alpha(r+2\pi)]>0$, this implies that the denominator is strictly positive, and it follows that $dL_T/d\Omega<0$.

We may now summarize the effects on the stationary equilibrium of an unexpected drop in the petroleum wealth which leads to permanently higher taxes. From (43) it follows that the drop in Ω implies higher stationary values for L_T, I and Q_T. The increase in L_T leads to reductions in X_N and Q_N, and according to (35) a drop in p_N. Correspondingly, C is lower since $p_N F_N$ is lower (see (40)), Y-T is lower (see (39)) and H is lower (see (38)). Equation (37) implies that V is closer to zero. Since Q_T is higher and $C_T=aC$ lower, the net import of traditional tradeables, $(C_T+G_T)-Q_T$, has decreased. Hence, the new stationary value of NW has decreased too, see (41).

4. THE ADJUSTMENT PROCESS

Initially, we assume that the economy is in a stationary equilibrium. Then, at time 0, an unexpected drop in the petroleum wealth leads to a corresponding drop in

$\Omega(0)$. In this section we analyze the gradual adjustment process which is triggered by an instantaneous and permanent tax increase which stabilizes Ω at a new and lower level, i.e. $T(0)$ jumps upward and $d\Omega/dt=dT/dt=0$ for $t>0$. In the next section we consider the effects of a tax policy which implies that the stabilization of Ω is delayed until period t^S ($t^S>0$ and $d\Omega/dt<0$ for $0\leq t\leq t^S$).

We assume at the outset that the permanent tax increase implies a drop in $H(0)$. Assume for a moment that the permanent tax increase leads to an increase in $H(0)$. Then, by the definition of $H(0)$ (see (11)), the increase in $\int_0^\infty Y(z)e^{-(r+\pi)z}dz$ must dominate the increase in $\int_0^\infty T(z)e^{-(r+\pi)z}dz$. This means that permanently higher taxes must lead to *increases* in $C(0)$ and $p_N(0)$. We disregard this rather unrealistic possibility.

The instant responses in the private production sectors and among the households facing a higher tax burden are influenced by the fact that $L_T(0)$ is fixed due to the training process needed for transfers of labor to the T-sector. This implies that $Q_N(0)$ will not respond since a downward jump would involve waste of N-sector specific labor. Hence, the drop in $H(0)$ implies that $C(0)$ and $C_T(0)$ drop, while $Q_N(0)$ and $C_N(0)$ are unchanged. It follows that $p_N(0)$ drops in order to clear the market for non-tradeables. Since (35) holds in the initial stationary equilibrium, the drop in $p_N(0)$ triggers transfers of labor from the N-sector to the T-sector, $dL_T/dt>0$ for $t>0$. Therefore, there is an immediate increase in the training activities at time 0, i.e. $I(0)$ jumps upward, and this implies corresponding drops in $X_T(0)$ and $Q_T(0)$. Obviously $Y(0)$ drops when $Q_N(0)$ is unchanged, $p_N(0)$ drops and $Q_T(0)$ drops.

From (28), it follows that $d\lambda/dt<0$ since $p_N(0)$ drops initially. According to (27), this implies that $dX_T/dt>0$. Since $dL_T/dt>0$, $dX_N/dt<0$. After the initial drop, Q_T gradually increases along with the increases in X_T and, sooner or later, these variables exceed their levels before the negative petroleum wealth shock. Correspondingly, $dQ_N/dt<0$. As the new stationary solution is approached, the need for more transfers of workers from the N-sector to the T-sector vanishes (dL_T/dt approaches zero) and I is stabilized at a level sufficient to train the relevant fraction of new workers (from the newborn generation) replacing those who die. So far, the analysis of the adjustment process is essentially equal to the analysis found in Steigum (1992). However, turning to the adjustment paths for consumption, human wealth, non-human wealth and the relative price of non-traded goods, the significance of the overlapping generations model structure is revealed.

Since the tax level is constant, (11) implies that changes in H follow exclusively from changes in the objective function (22). In order to argue that $dH/dt>0$ along the optimal adjustment path, we follow an indirect line of reasoning. First we consider the effect of $dL_T/dt>0$ (and $dX_T/dt>0$) on H under the temporary assumption that p_N is fixed after the initial drop. We define this as the "direct effect" of optimal structural adjustments on H. When structural adjustments are triggered at time 0, the drop in $H(0)$ is smaller than the hypothetical drop in the case of no structural adjustments.[6] Our question is whether the direct effect of $dL_T/dt>0$ may imply $dH/dt<0$ for any time interval $[t_0,t_1]$, $t_0 \geq 0$, $t_1>t_0$. At any instant after time 0 the gains from previous structural adjustments are maintained. The firms have the option to stop the structural adjustment process, and this would imply a stabilization of Y and H. However, the value of H realized from the *optimal* structural adjustments must be higher than the the value of H when the structural adjustments are stopped. Hence, we will argue that the direct effect of $dL_T/dt>0$ on H implies that $dH/dt>0$ when we keep p_N constant. If $dH/dt<0$ when p_N is constant, this must be due to too much training in the sense that the LHS of (29) is larger than the RHS. This possibility is contradicted by the fact that the behaviour of the firms implies that the condition in (29) is satisfied along the optimal adjustment path.

Turning to the analysis of the dynamic paths of H and C when we relax the assumption of a fixed p_N, a major question is whether the direct positive effect of

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[6] This follows from the fact that the upward jump in $I(0)$ reduces $Y(0)$, but increases $Y(t)$ for $t>0$ since the training process is instantaneous. The negative effect of a lower $Y(0)$ on $H(0)$ is more than offset by the positive effects on $H(0)$ of higher $Y(t)$ ($t>0$).

$dL_T/dt>0$ on H may be offset by reductions in p_N triggered by the development in the aggregate economy. First we consider the case of $\theta=r$ and start with a look at the adjustment path for consumption. We note that the non-human wealth of each newborn generation is zero and that the slope of the consumption path of each generation is flat when $\theta=r$ (see (8)). Because the economy is in a stationary equilibrium initially, $v(s,0)=0$ for all generations $s<0$. Their per capita consumption at time 0 is $(\theta+\pi)h(0)$ (see (7)), while the consumption level of a given generation born at time t $(t\geq 0)$ is $c(t,t)=(\theta+\pi)h(t)$. Hence, the consumption level of succeeding generations gradually increases if $h(t)$ increases. If $\theta=r$, it follows that the sign of $dC/dt>0$ is equal to the sign of dh/dt $(\equiv dH/dt)$.

Differentiating $p_N=p_N(C,L_T)$ with respect to time yields

$$(44) \qquad \frac{dp_N}{dt} = \frac{(1-a)}{F_N}\frac{dC}{dt} + \frac{p_N F_N'}{F_N}\frac{dL_T}{dt}.$$

The last term on the RHS of (44) reflects that the transfer of labor to the T-sector $(dL_T/dt>0)$ reduces the supply of non-traded goods, and this influences p_N positively. Since the sign of dC/dt is equal to the sign of dH/dt, $dp_N/dt>0$ if $dH/dt\geq 0$. The sign of dp_N/dt is undetermined if $dH/dt<0$.

In order to consider the development of Y we differentiate $Y=F_T(X_T)+p_N(C,L_T)F_N(X_N)$ with respect to time. This yields

$$(45) \qquad \frac{dY}{dt} = F_T'\frac{dX_T}{dt} + \frac{\partial p_N}{\partial C}\frac{dC}{dt}F_N + \frac{\partial p_N}{\partial L_T}\frac{dL_T}{dt}F_N - p_N F_N'\frac{dL_T}{dt}.$$

Using the fact that $\partial p_N/\partial C=(1-a)/F_N$ and $\partial p_N/\partial L_T=(p_N F_N')/F_N$ (see (30b)), we rewrite (45) as

$$(45b) \qquad \frac{dY}{dt} = F_T'\frac{dX_T}{dt} + (1-a)\frac{dC}{dt}.$$

Since $dX_T/dt>0$ and the sign of dC/dt is equal to the sign of dH/dt when $\theta=r$, we have $dY/dt>0$ if $dH/dt>0$.

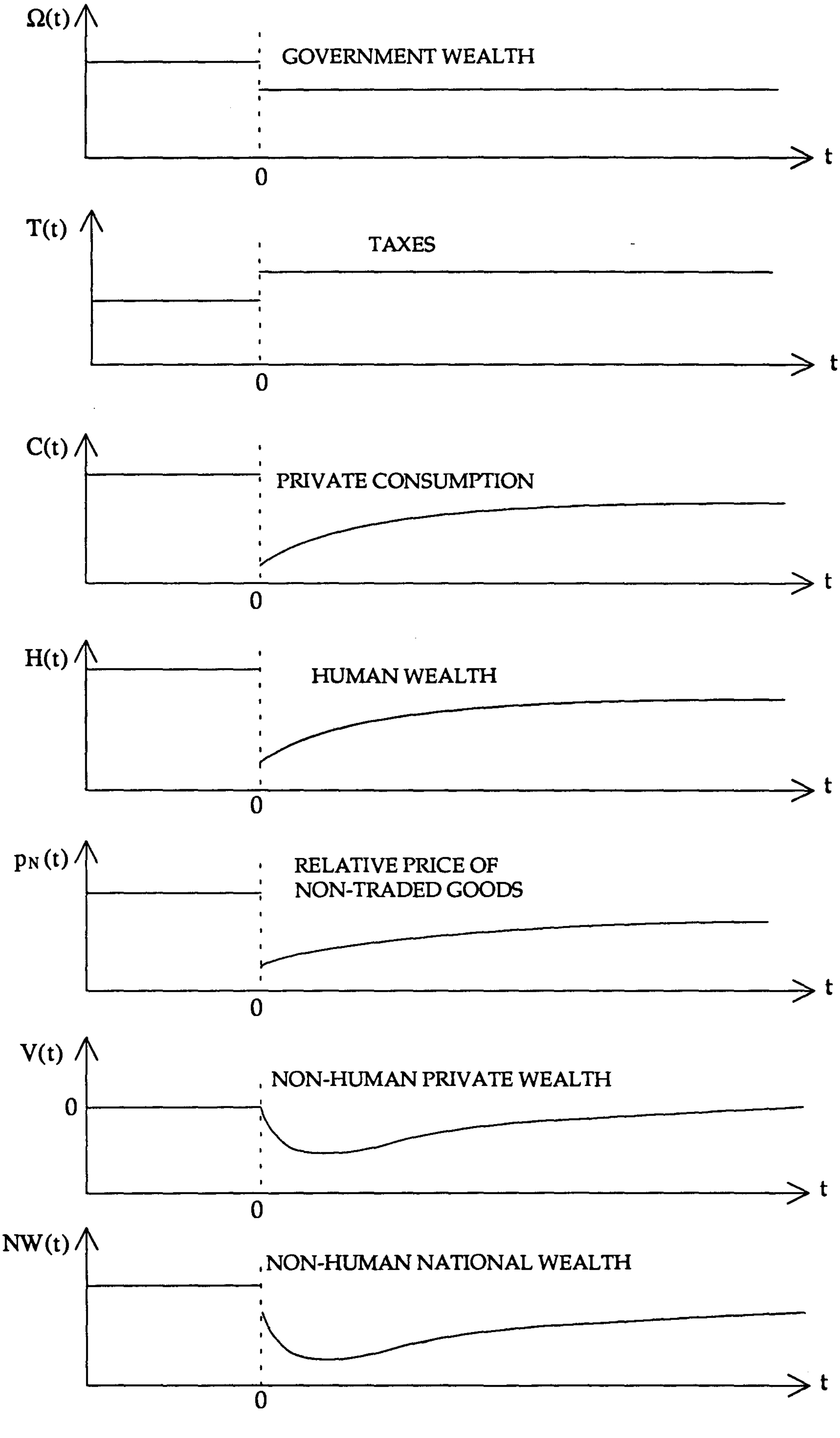
When the structural adjustment process is triggered at time *0*, we have argued that the "direct" effect of $dL_T/dt>0$ on H for a fixed p_N is positive. In turn, this positive effect on H ensures that $dp_N/dt>0$ and $dY/dt>0$ since the sign of dC/dt is solely determined by the sign of dH/dt. We can therefore disregard the possibility that the development of the aggregate economy implies reductions in p_N and Y. In the case of $\theta=r$ we conclude that $dp_N/dt>0$, $dY/dt>0$, $dH/dt>0$ and $dC/dt>0$. The new stationary levels of H, C and p_N are, of course, lower than the initial stationary level.

The composition of consumption (both individual and aggregate) is easily derived from the adjustment paths for C and p_N since the budget shares are constant over time. The consumption of tradeables ($C_T=aC$) increases gradually after the initial drop (but is, of course, stabilized at a lower level than the initial one), while the consumption of non-tradeables, $C_N=[(1-a)/p_N]C$, gradually decreases and is stabilized at a lower level as the new stationary equilibrium is approached.

When $\theta=r$, $V=0$ in both the initial and the new stationary equilibrium. The generations alive at time *0* face a drop in $h(0)$ and then gradually increasing values for h and y as the gains from training are realized. Since the consumption path is flat, consumption spending exceeds net income at the early stages after time *0*, and these generations go into debt. Similarly, generations born at the following instants go into debt since h and y are increasing. Succeeding generations borrow smaller amounts since h and y gradually come closer to their new stationary levels. It follows that V is gradually reduced for a period of time after time *0*. However, sooner or later the decumulation stops, and V starts to increase and approaches zero as time passes. Looking at national wealth, there is a drop in $NW(0)$ equal to the drop in $\Omega(0)$. Then NW gradually falls to an even lower level before it starts to increase and is stabilized at a level equal to the initial one minus drop in $\Omega(0)$, i.e. the dynamic path for NW reflects the path for V.

To summarize the analysis of the adjustment process in the case of $\theta=r$, figure 1 illustrates the dynamic paths of the different variables. The most striking observation is that H, C and p_N undershoot their new stationary equilibrium values. Our

Figure 1 **The adjustment process when $r = \theta$**



analysis shows that the generations alive at time 0 bear the largest burden of the total structural adjustment costs. Succeeding generations face gradually less adjustment costs and at the same time benefit fully from the transfers of labor in earlier periods. Looking for a moment at the model of Buiter (1988), a similar analysis of an unexpected drop in the government wealth would imply one-shot adjustments in Y, H and C since there are no adjustment costs in his model.

We have focused on how the adjustment process influences the consumption level of different generations. It is therefore interesting to note the consequences of an increased horizon. In the limit as π goes to zero, the horizon goes to infinity and no new generations are born.[7] In this case the whole population experiences both the drop in the petroleum wealth at time 0 and all the costs and gains of the following adjustment process. All the effects of the adjustment process on consumption are therefore reflected in the drop in $H(0)$, and it follows that the infinite horizon case implies an one-shot adjustment of the consumption path. This conclusion applies if we consider the effects of a drop in the petroleum wealth in the infinite horizon model of Steigum (1992) (who assumes $r=\theta$ throughout). Hence, we conclude that the undershooting tendency of C disappears as the horizon increases.

Turning to the cases where $\theta \neq r$, we consider only adjustment processes characterized by $dH/dt>0$. This means that we assume upfront that the positive direct effect of $dL_T/dt>0$ on H dominates potential negative effects on p_N (and H) caused by the development in the aggregate economy. In the case of $\theta>r$, we note that $v(s,0)<0$ for all generations $s<0$ in the initial stationary equilibrium (according to (8) and our assumption $v(s,s)=0$). Their per capita consumption at time 0 is $c(s,0)=(\theta+\pi)[h(0)+v(s,0)]$ (see (7)), and the initial consumption of a given generation born at time t ($t\geq 0$) is $c(t,t)=(\theta+\pi)h(0)$. In stationary equilibrium aggregate consumption is constant since the net impact of two opposite effects is zero, i.e. the consumption

[7] As discussed in section 2.1, we must have $\theta=r$ when $\pi=0$ in order to obtain a stationary equilibrium.

of each individual is decreasing, but the consumption of each new generation is larger than the consumption of those who die. During the adjustment process, the latter effect dominates since each new generation starts with a higher consumption level than the previous generation when $dH/dt>0$. Hence, $dC/dt>0$ and $dp_N/dt>0$. In the new stationary equilibrium V is closer to zero (the debt is smaller), see (37b). Because succeeding generations borrow smaller amounts as h and y approach their new stationary values, V increases gradually during the adjustment process.

Finally, we consider the case of $r>\theta$. In the initial stationary equilibrium $c(s,0)=(\theta+\pi)[h(0)+v(s,0)]$ and $v(s,0)>0$ for $s<0$. In stationary equilibrium the consumption of each individual is increasing, but the consumption of new generations is smaller than the consumption of those who die. The net effect is zero. During the adjustment process, the former effect dominates since the latter effect is weakened when $dH/dt>0$. Hence, $dC/dt>0$ and $dp_N/dt>0$. In the new stationary equilibrium V is closer to zero (the wealth is smaller), see (37b).

5. THE ADJUSTMENT PROCESS WHEN STABILIZATION IS DELAYED

In many countries we observe that fiscal stabilization after negative shocks in government wealth is delayed.[8] It is therefore interesting to discuss the effects of a drop in $\Omega(0)$ which leads to a further decummulation of Ω before the tax level is raised permanently at time t^S ($t^S>0$) in order to stabilize Ω. We define Ω^* as the stationary government wealth before time 0, $T^*=G-r\Omega^*$ as the corresponding tax level and the drop in $\Omega(0)$ as $\Delta\Omega(0)$. Instant stabilization of Ω (as in section 3) requires that $T(t)=G-r[\Omega^*-\Delta\Omega(0)]$ for $t\geq 0$. When stabilization is delayed until time t^S ($t^S>0$), it follows (for $0\leq t<t^S$) that $d\Omega/dt<0$ since $T(t)=T^*$ in this period. This implies that

[8] This phenomenon is explained within some politico-economic models, see for example Alesina and Drazen (1991).

(46) $$\Omega(t^S) = \Omega^* - \Delta\Omega(0) - \int_0^{t^s} e^{r(t^s-z)} r\Delta\Omega(0)dz\,,$$

where the last term on the RHS is the effect of the delayed tax increase. Stabilization of $\Omega(t^S)$ implies that

(47) $$T(t^S+k) = T^* + r\Delta\Omega(0) + r\int_0^{t^s} e^{r(t^s-z)} r\Delta\Omega(0)dz\,,$$

for $k \geq 0$. A longer delay, i.e. a larger t^S, means a larger upward jump in the new stationary tax level. Correspondingly, we obtain a higher value for L_T and lower values of H, C, p_N and NW in the new stationary equilibrium,

Before we consider the impact on the structural adjustment process, we take a closer look at the partial effect of the described reallocation of taxes on H. While the negative effect of delayed taxes on $H(t)$ for $t \geq t^S$ is obvious (from (47)), we will demonstrate that the effect on $H(0)$ (and on $H(t)$ for t slightly larger than 0) is positive due to finite horizons. Stabilization of $\Omega(t^S)$ implies, of course, that the government intertemporal budget constraint (18) is satisfied, i.e. it is easy to verify that

(48) $$\int_0^{t^s} e^{r(t^s-z)} r\Delta\Omega(0)dz = \int_{t^s}^{\infty} e^{-r(\eta-t^s)}\left(r\int_0^{t^s} e^{r(t^s-z)} r\Delta\Omega(0)dz \right) d\eta\,.$$

The LHS is the loss in government wealth due to delayed taxation, see (46). This loss must be equal to the RHS which is the value of increased taxation after time t^S, see (47).

Consider now the partial effect of delayed taxation on $H(0)$ (keeping Y constant). It follows from (11) and (48) that this effect is

(49) $$e^{(r+\pi)t^S}\left[\int_0^{t^S} e^{(r+\pi)(t^S-z)} r\Delta\Omega(0)dz \; - \int_{t^S}^{\infty} e^{-(r+\pi)(\eta-t^S)}\left(r\int_0^{t^S} e^{r(t^S-z)} r\Delta\Omega(0)dz \right)d\eta \right].$$

The first term in the brackets is the positive value of delayed tax increases, while the second term is the negative value of higher taxes after time t^S. By straightforward calculation, this expression is simplified to

(50) $$\frac{r\Delta\Omega(0)}{r+\pi}(1 - e^{-\pi t^S}).$$

Finite horizons ($\pi>0$) imply that this effect is positive and the longer the tax increase is delayed, the larger is the effect. The underlying reason for this result is the difference between the discount rates used in the calculation of the government budget constraint and in the calculation of H (r vs. $(r+\pi)$). When the tax increase is delayed, taxes are to some extent shifted to future generations and the generations alive at time 0 and the generations born slightly after time 0 gain. In the limit, as π approaches 0, the timing of taxes does not matter and this effect vanishes.

Turning to the production sectors, the mechanism behind the structural adjustment process is qualitatively similar to the case of instant stabilization. At time 0, $H(0)$ drops in response to a higher future tax burden, and this triggers structural adjustments. Since the partial effect on $H(0)$ of delayed taxation is positive (see (52)), the drop in $H(0)$ is smaller than in the case of instant stabilization. The longer the tax increase is delayed, the smaller is the effect on $H(0)$ and the smaller are the drops in $C(0)$, $p_N(0)$ and $C_T(0)$. As a consequence of a less dramatic response in $p_N(0)$, the immediate structural imbalance is smaller. Correspondingly, the upward jump in $I(0)$ is more modest, and the start of the process of transfering labor to the T-sector is more gradual.

The dynamic paths for H and C are determined by the joint effects of the tax policy and the structural adjustment process. In the case of instant stabilization, H and C undershoot their equilibrium values since the generations alive at time 0

were hit by both permanently higher taxes and the full burden of the transitory adjustment costs in production. When stabilization is delayed, the burden of increased taxation is to some extent shifted to future generations. In addition a more gradual start of the adjustment process implies that the present generations face lower adjustment costs. Both effects tend to reduce the drops in *H(0)* and *C(0)*. Looking at succeeding generations born after time *0*, they bear a larger tax burden but this is to some extent offset by lower adjustment costs, i.e. the generations facing a higher tax burden benefit from past structural adjustments.

We conclude that a delayed tax increase leads to a smoother intergenerational distribution of the structural adjustment costs. The present generations gain (compared to the case of instant stabilization) but in the new stationary equilibrium consumption is lower since taxes are permanently higher. Hence, in the timing of the fiscal restraint the government faces a trade-off between the welfare of the present generations (which are worst off in the case of instantaneous stabilization) and the welfare of future generations.[9] Naturally, the length of the time span between time *0* and time t^S is crucial for the magnitude of the intergenerational welfare effects.

6. CONCLUDING REMARKS

This paper considers a dynamic dependent economy model extended to incorporate finite horizons of the households and adjustment costs related to intersectoral transfer of labor. We analyze the effects of an unexpected drop in the government wealth interpreted as the result of a depreciation of the government petroleum revenues caused, for example, by a persistent negative oil price shock. If the tax level increases instantaneously in order to stabilize government wealth, consumption, human wealth and the relative price of non-traded goods undershoot their new stationary equilibrium values. The present generations experience both the

[9] The existence of this trade-off has obviously normative implications. An interesting problem which calls for a separate paper, is how the government should determine the *optimal* timing of the fiscal restraint.

permanent tax increase and the entire burden of the adjustment costs. Succeeding generations increase their consumption level since they face gradually less adjustment costs and at the same time benefit from past adjustments.

If the tax increase is delayed, the undershooting tendency is weakened. The negative effect of a higher tax level on human wealth and consumption is realized more slowly and this implies that the adjustment process is more gradual. In effect, the adjustment costs are distributed more evenly between the generations but the long run stationary consumption level is lowered due to a higher tax burden.

APPENDIX

Linearizing the dynamic system (13), (10b), (21b) and (26b) gives

$$
(A\text{-}1) \qquad \begin{bmatrix} \dfrac{dC}{dt} \\ \dfrac{dV}{dt} \\ \dfrac{dL_T}{dt} \\ \dfrac{d\lambda}{dt} \end{bmatrix} = \begin{bmatrix} (r-\theta) & -\pi(\pi+\theta) & 0 & 0 \\ \dfrac{\partial Y}{\partial C}-1 & r & \dfrac{\partial Y}{\partial L_T} & \dfrac{\partial Y}{\partial \lambda} \\ 0 & 0 & \dfrac{1}{\alpha}-\pi & -\dfrac{1}{\alpha}X_T'(\lambda) \\ \dfrac{\partial p_N}{\partial C}F_N' & 0 & \dfrac{\partial p_N}{\partial L_T}F_N'-F_N''p_N & -F_T''X_T'(\lambda)+(r+2\pi) \end{bmatrix} \begin{bmatrix} C \\ V \\ L_T \\ \lambda \end{bmatrix} .
$$

Using (27) it is easy to verify that $X_T'(\lambda)=1/(\alpha F_T'')$ and from (30b) we have $(\partial p_N/\partial C)=(1-a)/F_N$ and $(\partial p_N/\partial L_T)=(p_N F_N')/F_N$. This implies that $(\partial Y/\partial C)=1-a$, $(\partial Y/\partial L_T)=0$ and $(\partial Y/\partial \lambda)=F'_T/F_T''$. Hence, we may write the determinant of the state matrix in (A-1) as

$$
(A\text{-}2) \qquad \begin{vmatrix} (r-\theta) & -\pi(\pi+\theta) & 0 & 0 \\ -a & r & 0 & \dfrac{F_T'}{\alpha F_T''} \\ 0 & 0 & \dfrac{1}{\alpha}-\pi & -\dfrac{1}{\alpha^2 F_T''} \\ \dfrac{1-a}{F_N}F_N' & 0 & p_N\left[\dfrac{(F_N')^2}{F_N}-F_N''\right] & -\dfrac{1}{\alpha}+(r+2\pi) \end{vmatrix} .
$$

From (A-2) we derive (based on expansion by the first row) the characteristic equation as

$$
\begin{aligned}
(A\text{-}3) \qquad & (\alpha^{-1}-\pi-k)\cdot(-\alpha^{-1}+r+2\pi-k)\cdot\left[(r-\theta-k)(r-k) - a\pi(\pi+\theta)\right] \\
& + \frac{1}{\alpha^2 F_T''}\cdot p_N\left(\frac{(F_N')^2}{F_N}-F_N''\right)\cdot\left[(r-\theta-k)(r-k) - a\pi(\pi+\theta)\right] \\
& + \pi(\pi+\theta)\cdot\frac{-F_T'}{\alpha F_T''}\cdot(\alpha^{-1}-\pi-k)\cdot\frac{(1-a)}{F_N}F_N' = 0 .
\end{aligned}
$$

Equation (A-3) defines a fourth-degree polynomial, and it is rather difficult to solve explicitly for the eigenvalues $k=k_1,k_2,k_3,k_4$. However, we may utilize that the product of the eigenvalues is the determinant (A-2), i.e.

$$(A\text{-}4) \qquad \begin{aligned} k_1 \cdot k_2 \cdot k_3 \cdot k_4 &= (\alpha^{-1}-\pi)\cdot(-\alpha^{-1}+r+2\pi)\cdot\left[r(r-\theta) - a\pi(\pi+\theta)\right] \\ &+ \frac{1}{\alpha^2 F_T''}\cdot p_N\left(\frac{(F_N')^2}{F_N} - F_N''\right)\cdot\left[r(r-\theta) - a\pi(\pi+\theta)\right] \\ &+ \pi(\pi+\theta)\cdot\frac{-F_T'}{\alpha F_T''}\cdot(\alpha^{-1}-\pi)\cdot\frac{(1-a)}{F_N}F_N' . \end{aligned}$$

As discussed in section 2.6, two positive and two negative eigenvalues imply local saddle path stability since there are two predetermined variables (V and L_T) and two "jump-variables" (C and λ) in the dynamic system. This means that $k_1k_2k_3k_4>0$ is a necessary condition for saddle path stability. Looking at (A-5), we observe that the last term on the RHS (the third row) is always positive, while the sign of the two first terms on the RHS (first and second row) is determined by the sign of $r(r-\theta)-a\pi(\pi+\theta)$. If we assume $r(r-\theta)<a\pi(\pi+\theta)$ ($r\leq\theta$ or r not too much larger than θ), the necessary condition $k_1k_2k_3k_4>0$ is satisfied (remember that $1-\alpha(r+2\pi)>0$, see (28), and this implies that $-\alpha^{-1}+(r+2\pi)<0$). We also note that $r(r-\theta)<a\pi(\pi+\theta)$ ensures a negative relationship between the stationary values of L_T and Ω (see section 3).

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