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Norwegian Petroleum Fund
Investment Strategy Proposal

MERCER
Investment Consulting

Summary

Executive Summary

Financial markets are generally believed to offer investors increasing expected returns for increasing levels of (non diversifiable) investment risk. Strategic asset allocation for an institution involves choosing, from the various alternatives offered by these markets, the trade off between risk and return that is appropriate in terms of the objectives of the institution and the interests of the parties involved.

Once this choice is made, in practical terms, strategic asset allocation serves only as a *benchmark* to measure the management of the Fund. Decisions as to whether markets should be over or under weighted should be taken by management relative to this benchmark. This report does not take any views on the relative valuation of global markets. The issue of tactical asset allocation is beyond the scope of this report.

We begin by discussing a range of different approaches to setting strategic asset allocation. We see a number of important drawbacks in what has become the established method of addressing strategic asset allocation questions, namely the use of "long-term" models. The application of normative economic theories could provide an alternative, but are inconsistent with the stated objectives of the Fund. We have therefore turned to what may be called "Representative Investor" methods. We make a case, accepting some of the practical limitations, for the use of a global market capitalisation-weighted benchmark as the natural model portfolio for investment in global financial assets.

The liabilities of the Fund are not explicitly defined. One objective for the Fund, set out in 1997, made reference to the maintenance of value in terms of international purchasing power. In these terms, a portfolio of inflation-linked government bonds with duration equivalent to that of the Fund would minimise risk. We show, however, that on the assumption of a 25 year duration for the Fund, the available durations of bonds within inflation-linked markets around the world, combined with the fact that such bonds are not available in all currencies, means that material risk remains even under the "least risk" strategy.

Our central proposal is that the Fund should adopt a core portfolio managed to a market capitalisation benchmark of global assets. This benchmark currently implies around 50% (slightly more) in global equity markets and 50% in other assets (predominantly global investment grade bonds). We recommend that the currency exposure of the core portfolio should follow that of the assets comprising the market capitalisation benchmark.

The definition of the acceptable level of risk in the fund is unclear. If the level of equity exposure in the market capitalised benchmark is considered to be excessive then we recommend that this should form the "core" portfolio benchmark and a separate least risk

satellite portfolio should be constructed to mitigate risk.. To maintain equity exposure at levels broadly equivalent to the current strategy, a 75% allocation to the core portfolio and 25% to the satellite would be needed. However, we demonstrate that the overall difference in risk between the current strategy and the core market capitalisation weighted portfolio (without any satellite allocation) is relatively modest given the overall uncertainty in the Fund's liabilities and the definition of acceptable risk.

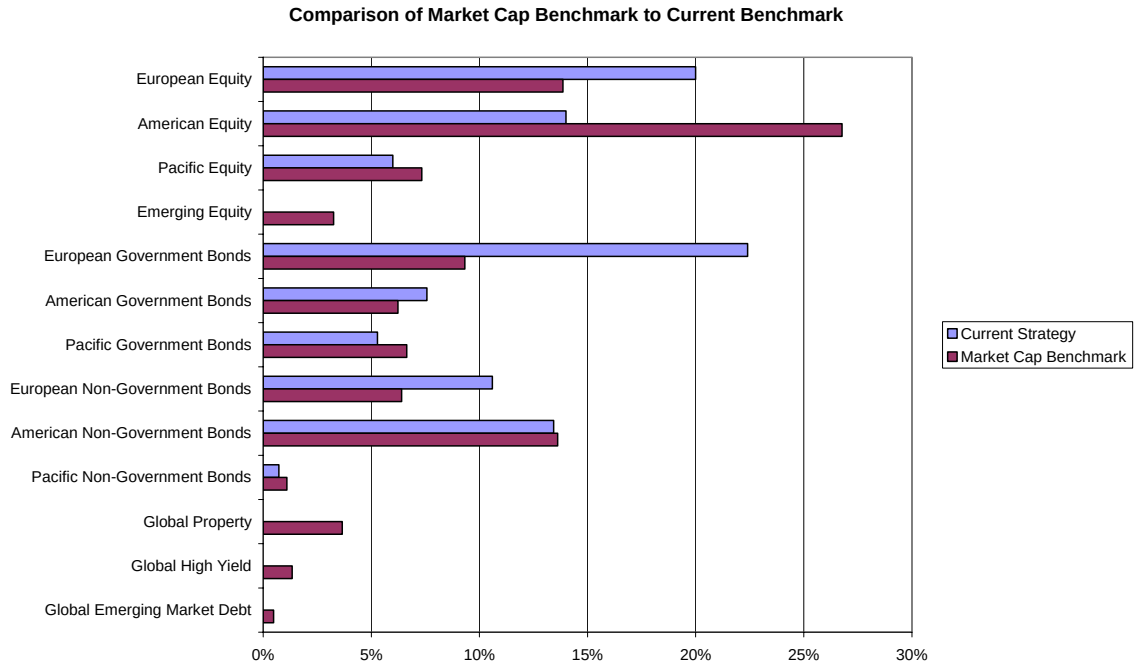
The global market capitalisation benchmark includes an allocation to small cap equities, real estate, emerging market sovereign debt, global high yield debt and private equity. In none of these asset classes do we consider it reasonable to expected abnormally high returns (in other words, greater than bonds and equities on a risk-adjusted basis). Their place in the strategy is justified if they offer a meaningful contribution to overall portfolio diversification.

Our analysis indicates that, although optimal in the purest sense, inclusion of emerging market debt and high yield, together with some equity small cap markets at their market capitalisation weights will have only a marginal impact upon overall expected return and risk. The case for including small cap allocations in the main equity markets (US, Europe and Japan) and Global Real Estate appears stronger on diversification grounds.

Given the absence of reliable data on private equity, this must be dealt with largely qualitatively. The potential difficulties in gaining initial exposure and subsequently managing it, in particular in terms of the general aim of operating the Fund on a transparent basis, would tend to argue against its inclusion in practice.

Inflation linked bonds will also in our opinion offer no material benefit when included at their market capitalised weight in a global benchmark. These bonds should be included only if a separate low risk "satellite" portfolio is constructed. This portfolio should adopt trade weighted currency exposures and invest in inflation linked bonds in economies where these are available. Constraints imposed by the size of the global inflation-linked bond market would argue against an allocation of more than 3% to any one inflation linked market. In other economies, or if the 3% limit on inflation linked exposure is exceeded, the satellite fund should invest in short to medium (10 year) maturity bonds. However, in view of the practical constraints preventing the Fund from investing in closely matched inflation linked bonds, we show that this satellite portfolio does not materially reduce risk relative to adopting the core market capitalised benchmark for the entire portfolio.

The chart below compares the current strategy to the market capitalisation portfolio:



In summary, the primary differences between our proposal and the current Fund strategy are;

- a higher overall equity allocation (by around 10% of the Fund) and correspondingly lower bond allocation;
- a greater bias to the US market, with a commensurately lower allocation to European markets;
- a more diversified benchmark within equity that includes smaller capitalisation stocks;
- an allocation to global real estate.

We have noted that the quantitative case for real estate is mitigated by the practicalities of easily accessing a diversified global exposure. The strictest interpretation of the market capitalisation portfolio would also see allocations to private equity, high yield and emerging market debt, but our analysis suggests that these asset classes offer only modest benefits in risk/return terms to the aggregate portfolio and practical considerations may favour their exclusion (practical considerations may also be a constraint on real estate investment as discussed in section 6.12 of the report).

Although we appear to have approached this review from a different angle when compared with previous studies, it should perhaps be noted that the above differences are

in our view relatively minor when seen in the overall context of the asset allocation for this Fund. There are also very important similarities between our conclusions and earlier studies, despite the apparent difference in approach. In particular;

- Both approaches involve a trade off between risk and return; neither involves minimising risk as an over arching objective. Even without the inclusion of the satellite portfolio to equate equity exposures, the basic risk and return trade off is rather similar between the two strategies (in the context of the much wider range of alternative possibilities).

- Both approaches use broad market capitalised market indices within individual asset categories to achieve diversification (our proposal merely extends this approach to the weights given to asset categories also).

Furthermore, some of the detailed changes (such as inclusion of real estate and small capitalisation stocks) have already been discussed positively as possibilities for the Fund. Thus our review should be seen as arriving, by different means, at conclusions that are broadly consistent with current policy and our proposals should in our view be seen as evolutionary rather than requiring fundamental change of policy.

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Introduction

1.1 The work on which this paper reports was commissioned by and is prepared in accordance with a contract with the Norwegian Ministry of Finance (the Ministry). The terms of reference for this work are set out in the Invitation to Tender issued by the Ministry to Mercer Investment Consulting (formerly known as William M Mercer Limited) on 13th May 2002.

1.2 The Requirement Specification described in the Public Procurement Basis states that:

> "The choice of asset allocation in the portfolio is a fundamental investment strategy issue and will be the main theme of the report. More specifically, the report must focus on different consequences of a possible change in the mix between equities and fixed income, a change in the benchmarks and the inclusion of new investment alternatives, for instance index linked (inflation protected bonds), private equities and real estate (commodities and hedge funds are not relevant)"

1.3 This report is addressed to the Ministry and presents formally the results of the work undertaken over the intervening year. The direction and focus of the work has evolved somewhat over time. Thus although our report covers all of the issues described in the above specification, certain issues have been raised to greater prominence (and others accordingly de-emphasised), to reflect our recommended approach to the fundamental investment strategy issue.

Jon Exley and Stephen Woodcock
For and on behalf of Mercer Investment Consulting

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Approaches to Setting Strategic Asset Allocation

Background

2.1 Financial markets are generally believed to offer investors increasing expected returns for increasing levels of (non diversifiable) investment risk. Strategic asset allocation for an institution involves choosing, from the various alternatives offered by these markets, the trade off between risk and return that is appropriate in terms of the objectives of the institution and the interests of the parties involved.

2.2 In practical terms, once established, the strategic asset allocation is then simply a *benchmark* against which the management decisions of the Fund can be measured. Thus, for example, if those responsible for the management of the Petroleum Fund have a view that, say, it should be underweight in US equities, the benchmark measures what we mean by "underweight". We mean underweight relative to the benchmark, as under or over weighting only has meaning in relative terms.

2.3 The actual returns earned on financial assets are of course beyond the control of investors, institutional or otherwise. One may wish to take views on whether certain financial markets offer abnormally high or low returns at the present time by reference to the risk and return trade off assumed for markets generally. However, such views fall beyond the scope of this report. An additional layer of management is required to make such decisions.

2.4 Since a departure from a long term trend can correct at any time, it is in fact difficult to distinguish between "long term" and "short term" views in any event. The additional layer of management required to make such decisions can thus be called tactical asset allocation or medium term strategy, but the important point is that all of the layers of management need to be measured against something, namely a benchmark[1].

[1] Some of the large Metropolitan local authority pension funds in the UK successfully adopt this additional tier of asset allocation management approach through the role of investment committees comprising (paid) advisers drawn from fund management and other investment industry sources. The tiered approach is also followed to a lesser extent by a small number of other large UK pension plans, although the freedom to take such active medium term asset allocation decisions is often stifled by the Trust status of these funds (which differs from the legal status of local authority funds). A similar approach is also adopted widely by insurance companies. In summary the UK experience seems to be that this approach is practical provided that responsibilities are clear (which is not the case for Trust based arrangements).

2.5 The role of the strategic asset allocation as defining a risk and return trade off and the view of strategy in practical terms as merely a benchmark reflect a more limited ambition than some previous aspirations of "strategic" asset allocations. The development of modern thinking on this issue is described further below.

The Development of Modern Approaches to Asset Allocation Benchmarks

2.6 The formulation of modern strategic asset allocation advice to institutions has undergone a substantial change in recent years. The failings of model–based approaches have led increasing numbers of practitioners towards approaches based on normative financial economic theory. Here, the role of modelling is subordinated below some over arching rationale for a particular approach (such as close hedging) rather than to determine a risk and return trade off in a classical portfolio selection framework. We describe below the differences between the two by way of an introduction to the review.

The "Long Term Model"-Based Approach

2.7 The model based approach grew out of the freedom created by modern computing power that enabled the application of statistical analysis to large volumes of data and the building of complex simulation models.

2.8 By the early 1990s all of the major Investment Consulting firms had their own proprietary model. Mercer Investment Consulting developed such a model in 1990 and the Mercer Global Capital Market Simulator is still widely used by pension funds, especially in the United States and the Netherlands.

2.9 These models all postulate relationships between various macro economic factors, asset yields and asset returns that are fitted to past data using standard statistical estimation techniques. The models are then used to simulate the development of asset portfolios, often relative to simulated liabilities, over very long horizons (twenty years).

Criticisms of the Model Based Approach

2.10 By the mid 1990s it had become apparent that these models did not necessarily provide robust answers to the problems that they were designed to solve:

i. Results are highly sensitive to expected return assumptions and robust methods of deriving these to within the tolerances required for asset allocation do not yet exist (aside from the "reverse engineering" adopted in this report but this takes a representative asset allocation as a starting point).

ii. The apparent sophistication of models often relies heavily on supposed artefacts of data such as "mean reversion" and yet modern research

suggests that such features could be observed even in random data. Quoting from the abstract of Engstrom (Draft, 2002)[2]:

> "...within a very general class of theoretical models, predictability regressions may be badly misspecified. In particular they have almost no power against the specific form of predictability suggested by reasonable treatments of risk. Additionally, simple predictive regressions produce estimates of the conditional risk premium which may be very different from the true values."

The basic problem with the alleged statistical significance of these mean reverting effects is that often both the explained variable (the next period return) and the explanatory variable (dividend yield, price/earnings yields, lagged returns etc) include a lagged endogenous variable (price). The importance of this violation of the condition for standard tests of statistical inference is not an easy concept to explain[3] (hence the relatively modern discovery of the issue) nor is it possible in general to derive an explicit formula for the bias it introduces. However, the effect can be uncovered by out of sample testing or by simulating the same regression for data known to be free of the effects being studied. For example, it can be shown that there is a relatively high probability of observing apparent mean reversion of equity yields in sample paths generated from simulation models known to have no mean reversion[4]. Another important criticism of assumed mean reversion in models is that although it does indeed justify a relatively minor bias towards more risky assets for long horizon investors, the main conclusion is that investors should use the apparent predictability of returns to change their policy dynamically. The latter approach will often in such models appear to generate large risk adjusted returns well in excess of those from fixed policies. Explaining why these returns cannot be earned in practice is a challenge for such models.

iii. The finance literature focuses mainly on positive rather than normative economic theory and gives little confidence in the ability of models to *predict* individuals' portfolio preferences. There is extensive literature on the "time diversification fallacy" which shows that intuitive beliefs about the way asset allocation preferences change with time horizon are often

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[2] A good summary of the modern criticisms of once widely held belief that the equity dividend price ratio is a simple mean reverting process is provided in "The Conditional Relationship Between the Equity Risk Premium and the Dividend Price Ratio" by E. Engstrom (Draft, November 2002) on http://www.gsb.columbia.edu/doctoral/students/job/ee68_dis.pdf. This refers back to the original work by C.R. Nelson & M.J.Kim "Predictable Stock Returns: The Role of Small Sample Bias" in Journal of Finance 48,2,641-661.

[3] A more general and shorter discussion of the biases in models is provided in "Avoiding biases in TAA Model Building" by L.Chaumeton & G.Connor on http://www.barra.com/Newsletter/NL163/ TAAModNL163.asp

[4] See "Mean Reversion and Market Predictability" by Jon Exley, Andrew Smith and Tom Wright, presented to the Finance and Investment Conference of the Actuarial Profession, June 2002.

fallacious. Quoting from the conclusion of the second chapter of Campbell & Viceira [5]

> "Does the investment horizon affect portfolio choice? ...we have shown that it may not. We have assumed that investors' relative risk aversion does not depend systematically on their wealth...Under this assumption, the investment horizon is irrelevant for investors who have only financial wealth and who face constant investment opportunities....Popular arguments,..., such as the claim that long term investors can afford to take greater risk because they have 'time to ride out the ups and down of the market', are simply wrong under these conditions".

iv. It is important to note that this does not rule out time horizon effects in portfolio choice, but it does dismiss intuitive reasoning behind these effects. For example it is not sufficient simply to point to the reduced probability of loss as time horizon increases. Despite this reduction in loss probability, the result referred to by Campbell & Viceira still proves that under some plausible investor assumptions, there would be no impact of time horizon on portfolio choice. The explanation for this is that although the intuitive analysis picks up the reduced probability of moderate losses, it does not pick up the increased probability of extreme losses along paths with repeated market falls. It is possible to construct models which show some time horizon effects, but they require more complexity and the horizon effect depends on the choice of parameters (e.g. mean reversion assumptions, see above) that are open to debate.

v. The use of arbitrary investment objectives, such as those based on arbitrary percentile outcomes, give arbitrary answers and, as discussed above, can mask important effects such as increased probability of extreme loss. This is well described by Norges Bank in "An Analysis of the Government Petroleum Fund Equity Allocation" (15 March 2001).

> "A common argument for increasing the equity proportion when the investment horizon is longer is the reduced probability that equities perform less favourably than alternative investments (shortfall risk falls). However, it is not sufficient to focus on the probability of a lower return on equities. It is important to consider how much lower the return on equities may be. Even though the probability of a lower return is reduced when the horizon is extended, the size of any lower return will increase"

Although assumptions in chosen utility functions such as "constant relative risk aversion" can be queried (see item iii above), the fact that plausible utility functions such as this can give very different answers from those

[5] See "Strategic Asset Allocation" by J.Y.Campbell & L.M.Viceira (2002).

obtained by use of arbitrary implied investor utilities should give cause for concern.

vi. Corporate financial theory argues that portfolio selection for institutions is fundamentally different from portfolio selection applied to an individual in any event. We discuss this further below.

In summary, although there is vast financial literature on the subject of portfolio selection most of the theory is essentially positive rather than normative. The existence or otherwise of time horizon effects is open to debate, but there is general agreement that intuitive beliefs about long term investors being able to "ride out the ups and down of the market" are simply wrong under some plausible assumptions. *These assumptions do not remove the possibility of time horizon effects but do provide a "counter example" to disprove commonplace reasoning*. Despite the attempts by practitioners to construct sophisticated long term models of asset classes, experience shows that these models do not arrive at robust recommendations (i.e. they are generally quite heavily parameter dependent, and it is difficult to determine the parameters precisely).

Approaches based on Normative Economic Theory

2.11 The theory reflected in (5) above is that conventional portfolio selection theory can only be applied at the level of individuals who ultimately bear the risks of institutional investment. Thus for a company pension fund, for example, we must track through the economics to identify who bears the investment risk (this might for example be shareholders or other individuals).

2.12 An adaptation of the Modigliani & Miller (1958) proposition suggests that these end investors are first order indifferent to the allocation of institutional assets to which they are exposed (on the grounds that they can in principle offset any institutional asset allocation by their choice of personal portfolio).

2.13 Second order issues (such as tax and frictional costs) are then the principal determinants of preferred institutional asset allocation. Essentially these second order issues determine how the choice of asset allocation of the institution can be used to maximise economic wealth. Modelling may be used to convert the theory into an actual benchmark (for example to determine a hedge portfolio), but the modelling required for such analysis will tend to be more subtle and sophisticated than conventional "risk versus return" portfolio selection (for example the modelling may adopt risk neutral assumptions).

2.14 The recent move by the £2.3bn Boots pension fund in the UK to 100% bond investment was an example of this approach. The primary decision to invest

100% in bonds was not based on modelling[6]. Supporters of the application of such normative theory explain the discrepancy seen elsewhere between observed institutional asset allocations and their theory in terms of principal-agent conflicts.

2.15 In the case of the Norwegian Petroleum Fund, the macro economic analogy of the theory used to support the simple matching of institutional assets and liabilities would be Ricardian equivalence. Under this theory, individuals would be assumed to have a strong bequest motive and behave rationally in such a way that the choice of Government policy in terms of both the decision to reduce taxes or set aside a fund, and the asset allocation of any fund, will have little impact on the economy. In this framework any Fund objectives would focus on minimising frictional costs and maximising transparency rather than a model based risk and return trade off.

2.16 However, it appears to be axiomatic that in creating the State fund, rather than reduce taxes, the objectives of the fund must extend beyond the minimisation of transaction costs, otherwise the Government would simply have reduced taxes. The starting point for the non-Ricardian approach is that the Government cares about the intertemporal allocation of the benefits of North Sea Oil and that it takes the view that not all consumers care about future generations.

2.17 It would appear therefore that the simplifications of the prescriptive theoretical approaches are not fully applicable to the Fund. Instead, the Fund's asset allocation must take account of the stated objectives of the Government, as decision-making agents, and their implied risk tolerances (again as agents rather than principals).

Representative Investor Approaches

2.18 In the absence of normative portfolio selection theory the most robust approaches to asset allocation tend to fall back on representative investor approaches.

2.19 These approaches start with the asset allocation of representative investors derived from actual asset allocation positions and then adjusts this position to allow for features of the particular investor(s) that make their situation different from that of the representative investor. The widespread references to the activities of other large institutions (CalPERS, OTPP, ABP etc) in the literature discussing the Fund's investment decisions is an example of an informal application of this approach.

[6] See for example http://www.gemstudy.com/defined_benefit_pensions.htm

Conclusions

2.20 Before relying on sophisticated long term modelling of the Petroleum Fund to set asset allocation it is important to ask two key questions:

vii. In what sense is the fund long term, relative to other investors?

viii. Even if it is long term, how reliable is the *normative* economic theory that quantifies how this long termism should impact on investment policy?

To the extent that the Fund is ultimately owned by Norwegian citizens (even if it is held on behalf of future generations, political control rests with current generations through the democratic process) the hurdle in (i) is not trivial. It could be argued that in economic terms the fund is no more long term than a typical representative Norwegian citizen. However, even if the Fund is dealt with in economically abstract terms as "belonging" to unborn generations with a long time horizon, the hurdle in (ii) remains to be overcome.

2.21 In our consideration of (ii), it is important to stress that we are not ruling out the possibility that time horizon could impact on portfolio choice, but we *are* ruling out any simple and widely accepted model for this behaviour. The issue is highly contentious (and parameter or model dependent) in the financial literature. In recent years there has even been back tracking on the general consensus on long term market modelling attributes (such as mean reversion) that once seemed to provide some rationale for time horizon effects (albeit still with difficulties in deriving conclusions from equilibrium models that displayed mean reversion).

2.22 Thus the main question we pose is *not* whether models can be built which purport to show prescriptive asset allocation solutions for the Fund – they can. The question is whether in practical terms the results of such models can be robust or reliable when compared with alternative approaches (such as representative investor comparison). Even if it were possible to construct reliable long term models of financial markets, the ability of portfolio selection theory to deliver a prescriptive solution is severely limited. The vast academic literature on this subject tends to explain observed behaviour rather than prescribe it.

2.23 Prescriptive solutions are offered by certain applications of financial theory that rely on first order indifference and thus fall outside conventional portfolio selection principles. However, these appear to be of only limited relevance to the Fund.

2.24 In the absence of prescriptive solutions, our firm opinion is that techniques based on representative investor behaviour provide the most robust approach. In practice any model based on positive economic theory tends to produce very similar results when compared with representative investor approaches in any

event. This is because positive theories must be calibrated against representative investor behaviour in the first place.

2.25 In the next section we will review the objectives of the Fund. In the subsequent section we will then propose a strategy based on a slightly more formal application of the representative investor approach that appears to meet the main objectives of the Fund and is broadly consistent with existing risk tolerances implicit in the decisions taken to date by Government.

3

Objectives of the Fund and Proposed Representative Investor Benchmark

Objectives

3.1 The Ministry of Finance stated the following in the discussion of the Revised National Budget for 1997:

> "In principle, the **objective** of the management of the Fund should be to invest the capital so that the Fund's international purchasing power is as high as possible at the time when it is likely that we will have to draw on the Fund, taking due account of an acceptable risk exposure. Overriding emphasis should be placed on the risk linked to the value of the Fund at the time that capital is to be drawn from the Fund. The risk that the Fund's returns will vary from one year to the next is of less importance in this connection".

The construction of this objective, if taken as read, gives only limited guidance. The reference to international purchasing power must logically be associated with the risk constraint, and not with the "as high as possible" return. (Whichever strategy maximises return will also maximise international purchasing power, making the reference to purchasing power redundant in the context of achieving the "high as possible" fund). Instead, we would thus read the objective as meaning "maximise the expected return on the fund subject to an acceptable risk, with risk measured in terms of international purchasing power".

3.2 However, even with this re-interpretation, we are left only with a reference to "acceptable" risk exposure. Furthermore, the reference to time horizon will be noted in connection with the discussion in the previous Section. Time horizon is only relevant if we choose to adopt a framework that admits time horizon dependent portfolio preferences. Although such frameworks do exist, their parameterisation is, as we have discussed previously, open to substantial subjectivity. Furthermore, again as discussed previously, simple and plausible frameworks exist that do not admit time horizon effects, regardless of parameter settings. In the absence of robust support for time horizon effects, we prefer to adopt a simpler and more practical approach.

Risk Minimisation

3.3 As discussed above, although the objectives of the fund suggest that an "acceptable" level of risk exposure can be allowed, there is no firm guidance

(other than the risk exposure implicit in the current Fund strategy) on what is an acceptable risk. A natural starting point is therefore to consider what a strategy that minimised risk would look like. Since this strategy minimises risk rather than eliminates it, it will still involve some risk in terms of international purchasing power. However, the "acceptable" level of risk can be no lower than this if the Fund is restricted to the conventional investible universe. (In theory counter parties such as banks will offer derivative contracts that replicate the purchasing power objective more closely, for example using contracts based on GDP, but not in the volumes required by the Fund).

3.4 A narrow interpretation of an objective that sought to minimise risk in terms of international purchasing power would define purchasing power in terms of the economies comprising the current trade weighted currency basket for Norway. The aim would then to be to preserve the value of consumption in these economies. This would suggest purchase of low risk real assets in each economy without any currency hedging.

3.5 The balance that needs to be struck between trade weighted currency exposure (biased towards economies close to Norway) and wider diversification in the global economy is discussed in the National Budget for 1998 (section 6.4 of the Budget report, titled "Investment of the Petroleum Fund"). The conclusion is that a compromise between import weights and GDP weights is appropriate. We will return to this issue in Section 5 but it suffices to note that even if the Fund adopts an objective of minimising risk in terms of purchasing power, there is still considerable uncertainty in terms of the basket of economies against which this risk should be measured.

3.6 In addition, there is a further complication. We have argued that the case for "time horizon" effects is weak in terms of preference for equities in portfolio selection models. However, we would argue that the case for different "least risk" strategies according to investor horizon is more robust. As described in "Strategic Asset Allocation" (Chapter 3) by Campbell and Viceira (2002), long dated inflation linked bonds are the least risk asset for a long term investor interested in preserving the consumption value of his wealth. This point is also made in the letter to the Ministry of Finance from Norges Bank dated 21 March 2001. Norges Bank tie together this duration issue and the choice of currency basket as follows (we replace the word "manager" with the word "investor"):

> The concept of "risk minimising instrument" can mean different investments for various investors. What constitutes a risk-minimising investment depends both on when the investor's obligations arise in future and the denomination of the obligations. For an investor with a very short horizon, an investment in short treasury bills can be an investment with little or no risk. For an investor with a long horizon an inflation linked government bond with a long maturity will be the closest one comes to a risk free investment. In both cases it is assumed that the instrument is denominated in the currencies that correspond to the investor's obligations. For the Petroleum Fund, a broad currency basket is relevant for measuring return and risk because such a currency basket will minimise the currency risk for the Fund's future international purchasing power.

3.7 For those economies in our international currency basket where inflation linked bonds exist, the least risk strategy for the Fund would therefore involve purchase of such bonds with appropriate duration. However, this introduces further imprecision into a least risk strategy as the "duration" of the Fund is not well defined. One approach, based on the "handlingsregelen" would be to assume that the Government will spend 4% of the real value of the Fund each year. This suggests a duration of around 25 years. On the other hand this 4% assumption was equated with an assumed real return on the Fund. Based on current real yields on inflation linked government bonds, an annual real return of only around 2.5%pa is more realistic (a payout of 4%pa would not be sustainable indefinitely). A payout of 2.5% pa would suggest a duration of 40 years. In practice, whether the duration of the Funds investment horizon is 25 or 40 years, they are both well beyond the duration of the longest available (coupon) bonds in issue.

3.8 It should be noted that inflation linked bonds perfectly hedge inflation (subject to Sovereign Government risk) in the economy in which they are indexed and on the basis of the index calculation only. The failure of indices to capture issues such as quality improvements is well documented. Nevertheless, inflation linked bonds are the perfect hedge for an (price index measured) inflation linked liability in the economy of that index. (Regressing inflation linked bond returns against inflation does not reveal this since there is a time component to risk associated with the real interest rate, but a liability to pay an inflation linked amount N years forward is exactly matched by an N year zero coupon inflation linked bond.)

3.9 The construction of a dedicated "satellite" portfolio aimed at minimising risk is discussed in more detail in Section 6. This discusses empirical research suggesting that the least risk real asset in economies with no inflation linked bonds would be short dated conventional bonds. The role for equities (and property) would be small even on the basis of optimistic (low) volatility assumptions for these assets (see for example Dyson & Exley 1995 and Smith [7](1998) in the context of matching National Average Earnings growth).

3.10 In summary, however, our conclusion at this stage is that *if*:

- the appropriate currency weights can be derived, and
- the (real) liabilities have an implicit duration of around 25 years

then a risk minimising benchmark would consist of long dated inflation linked bond indices (in those economies issuing such bonds) and conventional bonds with a maturity of around 10 years (in other economies). Although this minimises risk, even if the currency weights could be specified optimally, this still involves

[7] See http://www.gemstudy.com/defined_benefit_pensions.htm

material risk relative to a notional 25 year duration inflation linked liability (see below). Furthermore, based on current global real yields on inflation linked bonds the expected real return from such a bond orientated strategy would currently be in the region of only around 3%pa.

"Acceptable" Risk

3.11 The above discussion suggested that the role for equities in a risk minimising strategy would be minor, in the region of 10% at most. However, the objectives of the fund appear to extend beyond minimising the risk to purchasing power. We have noted in particular that the objective is interpreted more widely in the letter from Norges Bank to the Ministry (21 March 2002). This letter states that:

> an ideal strategy would be to own a portion of the instruments where the return directly or indirectly comes from future international production of goods and services.

This interpretation introduces the concept of returns to capital (since the Fund can only invest in financial assets) employed in the international production of goods and services. The current 40% equity allocation is well in excess of the level (around 10% equity or less) that would be consistent with minimising risk to purchasing power and is far more consistent with an objective that encompasses exposure to such risk capital. However, there does not appear to be any precise link between this wider objective and the 40% equity exposure in the publicly available Fund documentation.

3.12 Thus, in summary, the current policy reveals an implicit risk tolerance that equates with the equity exposure of around 40%, but this is working backwards from the current policy and not derived from the stated objectives. We see the stated objectives instead as reflecting merely the willingness of Government to tolerate some annual fluctuations in fund value and revealing a tolerance for risk beyond the simple risk minimisation policy described above, but does not define "acceptable risk" with any precision.

3.13 In order to estimate the risk associated with various investment strategies relative to long dated real liabilities, there are two basic approaches that could be followed. Firstly, we could build a model of the long term behaviour of various asset classes and a model of the long term (25 year) behaviour of inflation and we could analyse the risks of the former relative to the latter. However, there are pitfalls in this approach:

- We question the confidence that can be placed in any model of global inflation or financial asset returns over such long periods – there is simply not enough data to establish robust statistical relationships.

- Even if a model could be built, there is no obvious measure of risk over such long periods that can usefully be applied in the real world. For example if we

look at the probabilities of events happening over 25 year periods, it is not clear what probability level is acceptable (for an event that will in practical terms happen only once) nor is it clear how the risk will manifest itself in real time (given that the decision makers will need to account for and justify their decisions over a much shorter time horizon).

3.14 The second approach, which we would regard as the more modern stance, uses real time market data to derive risk measures, but involves approximations in this application. Conceptually, we would assume that a global inflation linked bond existed and we could observe the price movements of this bond relative to other financial assets. In this case it is clear that the Fund could exactly meet an objective of maintaining international purchasing power by investing in this bond (albeit perhaps expecting to earn only a low real return, given its riskless nature). Thus, the strategic risk taken by any investment policy could meaningfully be measured as the quarterly or annual (say) risk relative to the global inflation linked bond. The problem with this approach is of course that a global inflation linked bond does not exist – and even though inflation linked bonds do now exist in the US, the largest world economy, the data history is too short to derive useful quarterly or annual statistics.

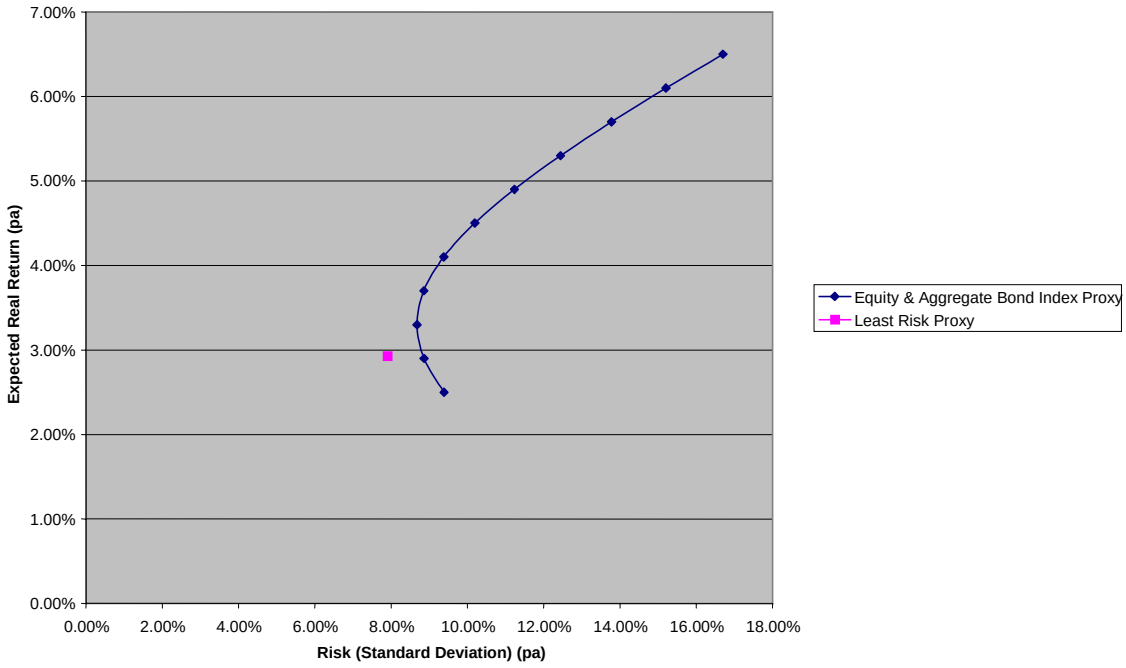
3.15 Nevertheless, given the pitfalls of the first approach, we prefer to adopt a proxy for the second conceptual approach described above in order to illustrate the risks associated with investment policies relative to long term inflation linked liabilities. Unfortunately, though, we need to use the UK economy as our proxy for these calculations. Throughout the world the UK is the only economy with a long (nearly twenty years since inception) history of inflation linked bond data from a large and reasonably well developed market (certainly over the last fifteen years). By measuring the risk of global equities (hedged into sterling) and sterling denominated bonds against UK inflation linked bonds using quarterly data over this period we thus derive a proxy for the risk of global equities and bonds relative to our notional global inflation linked bonds. (We also use the risk between short and long dated UK inflation linked bonds as a measure of the "duration" risk between short and long dated global inflation linked bonds). This assumes of course that the UK financial markets are representative of global experience and the results can thus be regarded as *indicative only*.

3.16 Using 15 years of quarterly UK data we can thus estimate annual risk of various investment policies, relative to a real liability with 25 year duration, and compare it with the characteristics of a "least risk" strategy. The "least risk" strategy is assumed to be 45% invested in aggregate inflation linked bond indices (duration 10 years) and 45% invested in appropriate duration (8 year duration) conventional bonds to reflect economies without inflation linked bond issues, with the remaining 10% invested in equities. The bond component of the equity/bond strategy is assumed to be fixed income only, with a duration of 5 years (as a proxy for the Lehman Aggregate index). We used currency hedged returns on the FTSE

world index as our proxy for equities and assume an equity risk premium of 4%pa.

	Relative Risk	Expected Real Return
Least Risk Strategy (aggregate)	8.0%pa	2.9%pa
40% World Equities, 60% Bonds	9.4%pa	4.1%pa

The risk and return characteristics, relative to the implicit liabilities, is shown below for a full range of strategies from 0% to 100% equities.



3.17 The current strategy represents one possible view of acceptable risk. As the diagram shows, the risk of this strategy is not substantially in excess of the risk associated with a "least risk" strategy (which for practical reasons is still quite a long way from an ideal match). The "flat nosed" shape of the efficient frontier in the vicinity of the current strategy suggests that the expected return rises quite significantly for relatively small increases in risk. However, the choice of the current risk versus return trade-off is ultimately subjective.

Transparency

3.18 Thus far we have established that even if the liabilities could be well defined (and in practice the choice of optimal currency weights is unclear, as is the precise duration of the liability), the Fund's objective does not appear to be minimisation of risk. To a certain extent our interpretation here is derived from what the objective *doesn't* say, since an objective of risk minimisation could have been expressed simply by Government in a few words. Nevertheless we have identified a risk minimising strategy, albeit with a large residual risk. The current strategy does not appear to increase this risk substantially, but the choice of risk level is subjective.

3.19 We have also noted that the Government's objectives refer to an acceptable level of risk, but this acceptability can only, we assume, be derived "backwards" from the current policy, which implies a certain risk tolerance.

3.20 In the context of this difficulty of deriving a strategy from the objectives set for the fund, we also note that another objective of the Fund appears to be transparency. This is referred to in many references to the Petroleum Fund. Although we have assumed that this is not a critical objective in determining strategy, the fact that the strategy currently adopted is difficult to rationalise precisely in terms of the stated objectives could be said to involve a lack of transparency in the decision making process.

Conclusions

3.21 Given this lack of precision in the objectives, we will consider in the next section the possibility of adopting a new, transparent, approach to setting strategy arriving at an equity exposure in "core" strategy that is currently close to, but slightly above, that of the current strategy.

3.22 In view of the uncertainty in the "acceptable" level of risk in the Fund, and the shape of the "efficient frontier" described above, it would seem possible that the slight increase in equity exposure in the core strategy may be tolerated, but we do not pre judge this issue. However, having established the "least risk" strategy (albeit with a high degree of residual risk), the overall equity exposure can be controlled, if required, by combining our "core" strategy discussed in the following sections with a "satellite" strategy with a risk minimisation objective.

3.23 We return to this core/satellite construction in the final Section 6. In the meantime we will concentrate on the core strategy, with an implied risk exposure slightly in excess of that *implied* by the current strategy (albeit not necessarily outside the risk tolerance that could be inferred from the stated objective).

4

The Market Capitalisation Weighted Benchmark

Introduction

4.1 The natural "model" portfolio of global financial assets is a market capitalisation weighted benchmark.

4.2 The market portfolio has special status under the assumptions of the Capital Asset Pricing Model (CAPM), *but the appeal of this portfolio is not dependent on CAPM alone*. Arguably, the CAPM equilibrium model seeks to ensure that investors hold this market portfolio precisely because it is a *prerequisite* of any equilibrium model to explain why in aggregate investors hold this market portfolio – the CAPM model just happens to be the simplest equilibrium model achieving this.

4.3 We will reiterate several times that the main "theoretical" justification for global market capitalised weights is based on the simple "adding up" rule that ensures that the "average" global investor must hold this portfolio.

4.4 We will consider the relevance (or otherwise) of some of the other theoretical arguments for a market capitalised benchmark below. However we focus firstly (and primarily) on the practical and investment issues.

Practical Issues

4.5 Market capitalisation weighted benchmarks have a number of distinct practical advantages.

4.6 On the other hand, the letter from Norges Bank to the Ministry of Finance dated 21 March 2001 covers a number of practical criticisms of market weights:

ix. The portfolio that is managed is not sufficiently large for all available alternatives to be represented in a meaningful way.

x. The marginal diversification gains decline as more assets are included in the portfolio.

xi. A number of instruments are so highly correlated that the gains that can be achieved from including all the instruments are marginal compared with investing in a smaller selection.

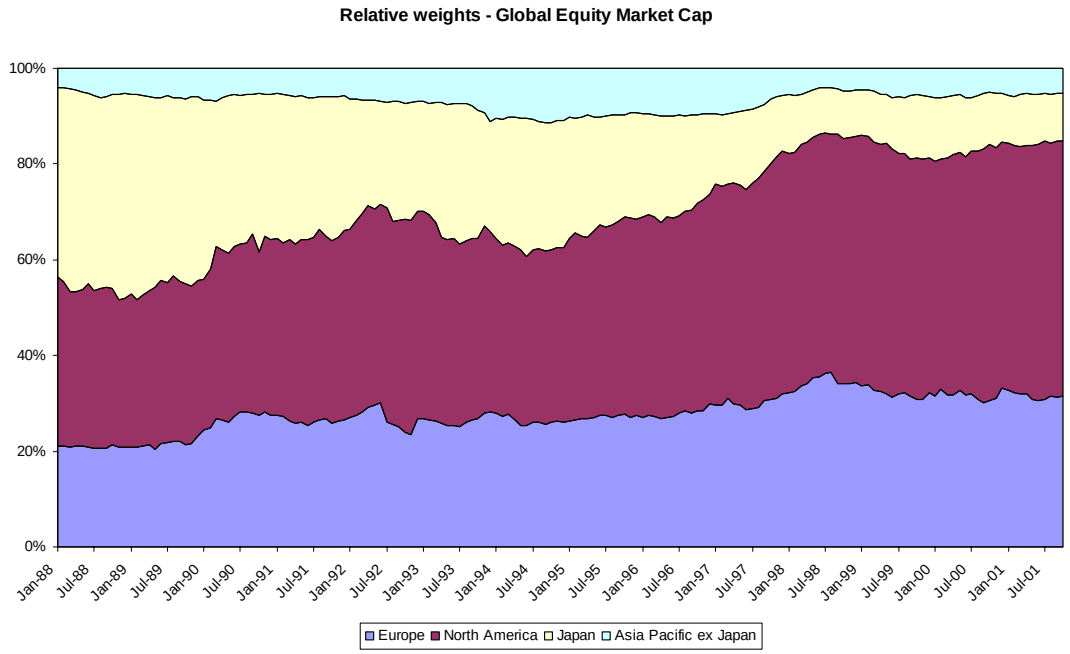
We have little to add to these criticisms and they will form the basis of our analysis in later sections. We address these issues by starting with the Global Market Capitalised Portfolio as representative of the portfolio of financial assets held by the average global investor (see above). We then use the machinery of the CAPM model to fine tune our analysis. In other words we will actually use CAPM as an effective tool to analyse these issues rather than using these issues to reject CAPM.

4.7 Some other practical drawbacks relate to the details of construction of a market capitalisation index.

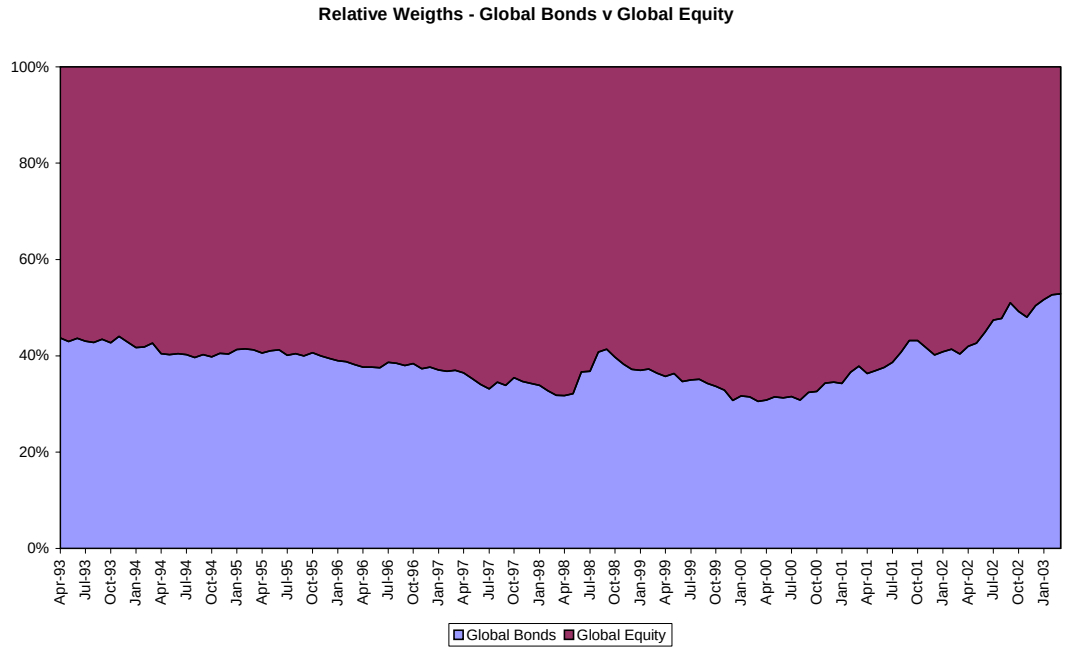
However, we do not consider these to be serious drawbacks when compared with the practical advantages and underpinning theoretical and "transparency" advantages of market capitalisation weights as a model exposure to global financial assets. Although adjustments could be made to the recognised market capitalised indices, the practical benefit of these adjustments would need to be weighed against the added complexity, and possible subjectivity, involved.

Investment Issues

4.8 The relative weights between different geographic regions and asset classes have varied significantly over recent history. This can be observed in the graphs below which shows the relative movements in the different components of Global Equity Market Cap, and in the latter graph between Global Equity and Global Bonds.



Source: MSCI



Source: MSCI and Lehman Brothers

4.9 Investment practitioners would level a number of criticisms at a global market capitalised benchmark from an investment perspective.

i. Given the fluctuations shown above, it is easy with hindsight to give examples where a market weighted benchmark would have bought a market "at the top" and underperformed some arbitrary fixed weights. Often such fixed weights are rationalised in terms of GDP weights, although it is unclear why GDP weights are appropriate for financial assets. Other times fixed weights are described as "natural diversification" – such as investing one third in each main economic bloc – although the choice of the definitions of economic blocs and the arguments for equal weights seem even less justifiable than GDP weights. However, when these non-market weights are chosen without the benefit of hindsight, it is less easy to demonstrate that they necessarily out perform.

ii. There is a widespread belief among investment practitioners that markets mean revert. Some of the reasons why mean reversion tends to be observed "in sample" but not "out of sample" were discussed, with references, in Section 1 (the phenomenon of "small sample bias"). If markets do mean revert then fixed weights will out perform. However, it should be noted that it is possible for capitalised values of markets to mean revert without investors seeing mean reverting returns – for example by the issuance of new capital.

iii. The mathematical artefacts of a rebalancing policy may be confused with the actual value of the policy. For example, if we invest NKr 100 in one fund adopting a fixed weight asset allocation and NKr 100 in another fund with no rebalancing (akin to market weights), they both obviously have a value now of NKr 100. In other words knowledge of future rebalancing policy does not (ignoring transaction costs) add to the value of a portfolio today.

iv. Many practitioners accept the principles of market weights selectively.

v. As we discuss below, the intuitive appeal of market weights as capturing global production is less strong in the case of Government debt. However, the general principle of holding a portfolio of global financial assets that is representative of a global average investor remains in force.

4.10 From an investment viewpoint, it should be noted that the risk of a market capitalised portfolio may vary over time due to the equity versus bond weights changing. This change in weights over time is not inevitable, for example even if equities return 50% more than bonds, it is possible that Governments will issue 50% more bonds, thus keeping market weights constant. However, market

movements could easily return the equity weight back to nearer 70% (the level at the beginning of 2000).

4.11 In the next section we will compare this portfolio with the current strategy in terms of various risk factor exposures.

Theory – Relationship with CAPM

4.12 Seen in isolation, the CAPM based argument for market capitalisation weights is naturally open to a number of criticisms. These are also described in the letter from Norges Bank to the Ministry of Finance dated 21 March 2001.

Our aim here is *not* to offer an uncompromising defence of CAPM, the limitations of the theory are well known. CAPM is remarkable because as a simple model it can give insight, but as a simple model it is clearly open to many criticisms. In our view the model is more defensible as a simple tool for the "perturbation" analysis that we propose.

4.13 However, in response to these criticisms we would note that the main alleged weakness of CAPM under the first criticism is probably "home bias", which is a consequence of imperfect capital mobility. This is discussed in V.Errunza, K.Hogan and M-W, Hung[8]. The abstract of this paper reads as follows:

We examine whether portfolios of domestically traded securities can mimic foreign indices so that investment in assets that trade only abroad is not necessary to exhaust the gains from international diversification. We use monthly data from 1976 to 1993 for seven developed and nine emerging markets. Return correlations, mean-variance spanning, and Sharpe ratio tests provide strong evidence that gains beyond those attainable through home-made diversification have become statistically and economically insignificant. Finally, we show that the incremental gains from international diversification beyond home-made diversification portfolios have diminished over time in a way consistent with changes in investment barriers.

We cite these results to suggest that apparent home bias in investor portfolios is not in itself an argument against the CAPM framework.

4.14 In response to the second criticism, the assumption that investors are concerned only with the first two moments of return is a restrictive assumption, but it is shared by many other applications (if not all applications) of "mean-variance" analysis. Whilst one can finesse the characterisation of risk to higher moments,

[8] "Can the Gains from International Diversification Be Achieved without Trading Abroad?" (Journal of Finance, Vol LIV, No.6 December 1999 pp 2075-2107)

or "downside" measures, it becomes difficult to determine which risk measure concerns any particular group of investors.

4.15 In fact, in dealing with all of these three criticisms, the fundamental issue to which we return is that even without the CAPM assumptions, arithmetic (adding up the portfolio of every investor in the world) determines that the market portfolio must be the "average investor's" portfolio of financial assets. If we start instead with this as our justification for market weights, then we will need a model (such as CAPM) only to determine how the characteristics of an individual investor determine *perturbations* from this position. It is our view that, given all of the other uncertainties in Fund objectives, and the appeal of a simple and transparent approach, such adjustments are not necessary.

Theory - "Ricardian" Analysis

4.16 Although we have not assumed this to be an overriding objective, the choice of the average investors' portfolio under the market capitalisation approach does also have some appeal even from a Ricardian standpoint (taking as given that the assets are not simply given back to individuals).

4.17 Although the Petroleum assets represent only around 6-7% of total National Wealth, given that the remaining wealth is dominated by human capital (around 80%) it would appear that this fund could form a high proportion of Norwegians' total financial assets. If we assume that the average Norwegian individual would rationally adopt this market capitalised asset allocation (or a home made proxy) out of choice, then it is arguable that the market allocation of the Fund minimises transaction costs borne by individuals in achieving their desired personal portfolio.

4.18 Seen from this Norwegian individual's perspective one of the more pertinent arguments against market capitalisation weights as representative of his preferred asset allocation is that different investors around the world may have different "hidden" non financial assets. Ideally all of these assets should be included in any analysis but in practical terms such adjustments would be problematic and would again destroy the simplicity of the approach.

Theory – Global Production

4.19 From a macro economic standpoint, the existence of substantial non financial assets also undermines more ambitious claims for the market capitalisation portfolio as representative of global production. Whilst this characterisation of a market capitalised portfolio has strong appeal in satisfying the objectives of the Fund discussed in the previous section, it must be acknowledged that the market capitalised portfolio unfortunately captures only part of this global aggregate.

However, the main missing component in the replication of global production is of course the value of human capital. If it could be argued that Norwegian citizens' own human capital is a proxy for this then combining the market capitalisation portfolio with this personal human capital may not be far away from a representation of total production. This is simply a restatement of the problem of hidden non-financial assets, with human capital being the largest item.

4.20 Once again, although these macro economic aspects can be discussed further, we see no strong argument against the use of a market capitalised benchmark from this standpoint.

Summary

4.21 We have stressed the practical aspect of market weights. We will use theories such as CAPM only at a secondary level – to analyse the impact of including or excluding certain assets from the market portfolio. This is in our view a robust way of using such models.

4.22 If modelling is used in this way (ie starting with the market weights and using CAPM to back out the benefits of diversification) then from the perspective of the management of the fund, this "modelling" approach also offers a straightforward asset allocation process. If a new asset class is to be considered then we need only ask:

a. What is its weight in the market portfolio?; and

b. Is the improvement to the risk and return profile worthwhile?

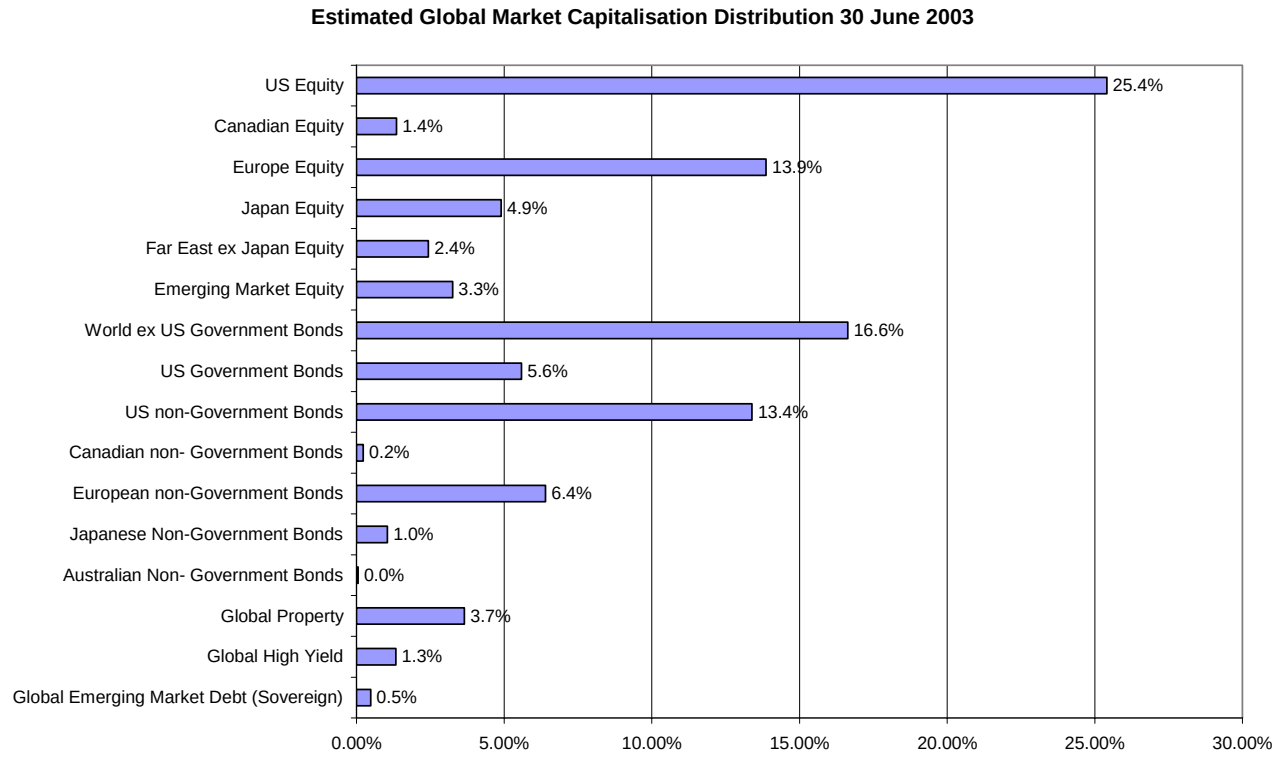
4.23 In terms of more conventional model based "risk analysis", we will mainly restrict this to an analysis in the next section of the main risk factor exposures in the market portfolio. We consider this approach to be consistent with the fact that even if risk could be modelled accurately over long periods the objectives do not in any event give precise guidance as to what is "acceptable" to within the tolerances required to make such detailed analysis worthwhile.

5

Analysis of Risk Exposures of Global Market Capitalisation Portfolio

Composition

5.1 In broad terms a global market capitalisation portfolio looked as shown in the graph below as at 30 June 2002, based on Salomon Smith Barney data for equities, Lehman Brothers and Merrill Lynch data for bonds and using data for total investible market in Real Estate supplied by Hendersons, but adjusted to allow approximately for the component of the property market held by listed companies (which is already implicitly included in the equity market valuations):



5.2 The equity weights use SSB estimates of total market capitalisation (i.e. beyond those covered by the standard SSB indices, which incorporate free float adjustments). We believe this to be consistent with the principles of the market capitalisation approach. We have not made any adjustments for cross holdings by institutions such as pension funds, although it is estimated that the US equity market for example is over stated by about 10% due to this effect.

5.3 The 4% weight for real estate holdings is also approximate and represents an adjustment to allow for property holdings of listed companies. It is appropriate to make allowance for this form of cross holding as it is significant – an estimated two thirds of institutionally investible global property assets are held by listed companies. We have used a figure for total property assets from Henderson Global Investors, Revisiting the Case for Global Property Investment, November 2002 and reduced it by two thirds.

5.4 Whilst we are open to further discussions on the details of the construction of the above benchmark weights, our overall view is that there is in practice some conflict between the theoretical principles behind the market capitalisation approach and the principle of transparency. Whilst theoretically all of the allocations can be questioned, we believe that from a transparency perspective, a generally accepted publicly available statistic is more credible than one subject to overly detailed adjustments.

Primary Asset Exposure

5.5 The striking feature of the above market portfolio is in how close this portfolio is (within the tolerances of an alternative model based solution and within the uncertainty of the "acceptable" risk tolerance implied by the Fund objective) to the current strategy. (This is of course partly a function of the recent falls in equity values).

5.6 The important risk exposure to note is that the above portfolio has an equity allocation of 52% (as at end November 2002). This is 12% higher than the current equity exposure. The increase in equity allocation would be largely accounted for by benchmark allocations to the smaller capitalisation equities excluded from the current standard benchmark FTSE All World benchmark indices (we understand that existing smaller company portfolios are effectively "off benchmark").

5.7 It is generally accepted that the characteristics of Real Estate fall mid way between equities and fixed income. On this basis, combining one half of the Real Estate allocation with the equity allocation, plus one half of the emerging market debt and high yield bond allocations (also with equity characteristics) suggests that overall the market capitalised portfolio has around 15% more equity exposure (as at end November 2002) when compared with the current 40% equity benchmark of the Fund.

5.8 We have already shown in Section 2 the approximate risk of various equity and bond allocations. This is intended to be indicative only.

It will be seen that risk does vary depending on the implicit liabilities against which risk is measured. The impact of implicit liabilities in affecting risk is one justification for "time horizon" effects, although it will be seen that the impact varies depending on the risk level.

5.9 The shortcomings of using the UK data as a proxy for this analysis can be seen by comparing the absolute risk for the 52% equity strategy (roughly 9.7%pa) with the risk calculated for the Global Market Portfolio (around 8.3%, as discussed below). This illustrates the benefits of international diversification that cannot be captured in a single country model.

Approximate Risk Profile

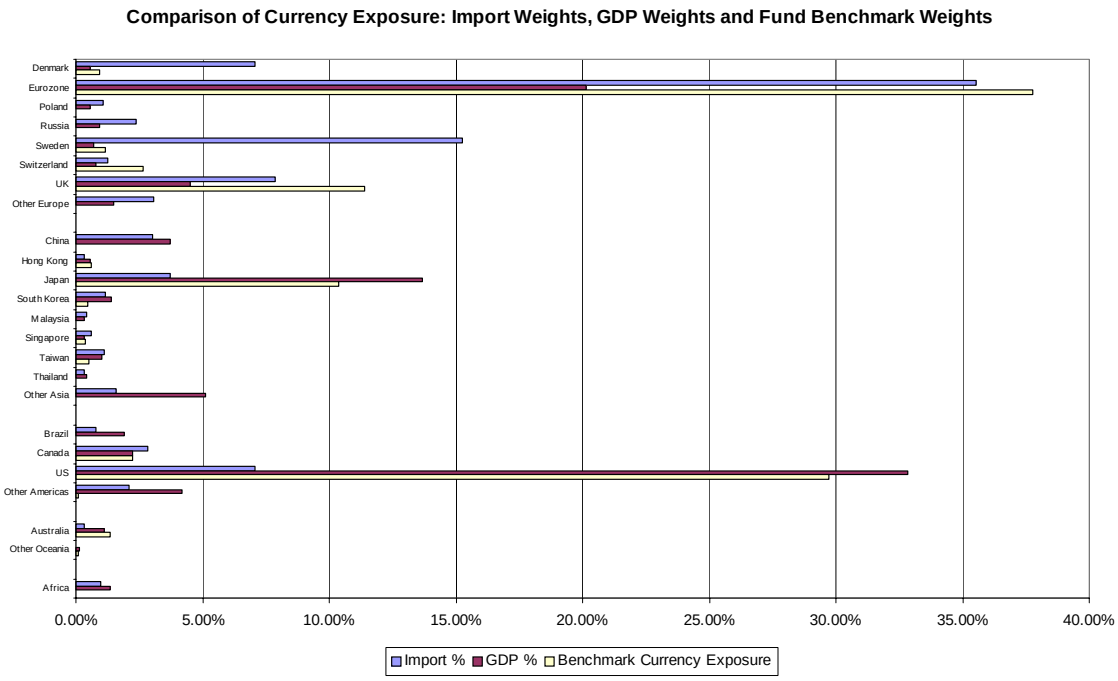
5.10 As discussed above, the absence of data on a global inflation linked bond market makes it impossible to analyse risk reliably relative to an (implicit) long duration inflation linked liability. However, the analysis above also suggests that for equity allocations in the region of 50% (using UK data) the difference in risk measured in absolute terms and measured relative to such a liability may not be substantial (in the context of the precision in the risk tolerance).

5.11 The covariance matrix used for our risk calculations is set out in Appendix A. This uses monthly data covering the longest available time periods for each asset class.

5.12 We have therefore calculated the risk of the market capitalised portfolio in absolute terms, for which a long data series is available. We calculate the risk as 8.25%pa. More importantly we have used bootstrapping methods with actual monthly data to simulate the distribution of returns from this portfolio.

Currency Exposures

5.13 The table below compares the implicit currency exposure of the market capitalisation weighted strategy with the current exposures and with import weights and global GDP weights.



The implicit currency exposures achieved with the use of market capitalisation benchmark weights could be modified by the use of currency hedging (or, if the Fund establishes a minimum risk "satellite" asset pool as described in Section 2, by altering the currency weights in this pool).

5.14 The proposed benchmark clearly has a greater exposure to US Dollars and lower exposure to the Euro when compared with the current strategy. The current exposure to currency is a compromise between import weights and global GDP weights. However, it is unclear why global GDP weights are preferred over market capitalisation weights. GDP is a backward looking accounting aggregate only and the weights are not representative of the *present value* of total global GDP. Weighting the currency exposures of financial asset values (which *do* represent present values) with these historic accounting aggregates therefore mixes two different quantities.

5.15 If we regarded market capitalisation weights as representative of the value of future production (the inherent approximations were discussed in section 2) then it would be implicit that the currency exposures of these market weights would not require any adjustment. The fact that market capitalisation weights of financial

assets represent only a proxy for this production does however leave room for the correct weights to be closer to GDP weights.

5.16 However, the use of unadjusted market capitalisation weights has the benefit of simplicity and avoids spurious adjustments such as treating all earnings of US listed companies as US Dollar denominated – in reality some of the earnings will be in Euros. Furthermore, if currency hedges were put in place then the Fund would see ownership of a fluctuating proportion of global financial assets that would be difficult to justify. By adopting the currency weights implied by the market weights, the Fund would (in principle) own a constant proportion of these assets over time.

Interest Rate Risk

5.17 The Fund currently uses Lehman Aggregate Indices for its bond exposure and, as such, the duration should not be markedly different from the global market cap portfolio, although the underweighting of Japan by the Fund may have a small impact. The duration of the Lehman aggregate world index is currently just under 5 years.

5.18 A small difference in the duration of the bond portfolio is not a major contributor to the overall risk profile of the fund. In broad terms interest rate volatility is likely to be in the region of 0.5% to 1%pa, but it is imperfectly correlated with equity risk, which is the main risk factor.

5.19 As discussed in Section 2, the Fund has an implicit liability that could be matched with inflation- linked bonds. It could thus be argued that the bond portfolio should be modified to reflect the fact that the Fund measures risk relative to this liability, rather than relative to cash. Based on the approximate result that the duration of the conventional bond portfolio should be around one third of the duration of the real liability this would in fact probably suggest adopting a slightly longer duration bond benchmark. However, such adjustments would in our view contribute little in practical terms whilst complicating the simplicity of the market capitalisation approach.

Sector Exposures

5.20 Both the current strategy and the proposed strategy adopt unadjusted sector exposures, although whilst the oil reserves exist a case could be made for adjusting the equity benchmark by exclusion of, say, equities in the Oil & Gas sector of the index. These currently account for around 7% of global market capitalisation (source: Salomon Brothers).

5.21 Of course, in principle bonds issued by companies in this sector should also then be excluded.

5.22 The exclusion of this sector would, however, allow the Fund to adopt a global market benchmark with less adjustment to the existing equity versus bond split.

5.23 In principle this analysis could be extended to other assets with an *empirical* (observed historical) correlation with oil wealth so as to produce a statistical *tilt* of the whole portfolio away from oil wealth. However, such tilts are in danger of focussing on relationships occurring by chance in the data. By contrast, the Oil and Gas sector of the equity market has a plausible theoretical justification for a link with oil prices which is merely confirmed by statistical analysis. In general, use of statistical analysis to confirm a theoretical prior is a far more reliable approach than reliance on statistical relationships alone.

5.24 Having said all of this, the exclusion of an entire sector from the Fund's equity exposure would be a major decision and has knock on implications in a number of other areas, such as the overall diversification of the equity portfolio. We would therefore recommend that further research is carried out before a final decision is made on this issue.

6

Diversification Gains within Market Portfolio

6.1 In this section we use some of the theory behind the market capitalisation weighted portfolio under CAPM to derive risk and return characteristics of the current portfolio, we then use these to *rank* the actual diversification gains from including various asset classes in the market portfolio benchmark.

The Approach

6.2 In the previous section we introduced the market capitalisation weighted portfolio as our model asset allocation for a typical investor. We can use the assumptions underlying the Capital Asset Pricing Model to derive from this portfolio the expected excess returns (over the risk free return in the base currency) on the constituent assets.

6.3 Given that currency risk can in theory be hedged at no cost by any global investor, we work with currency hedged returns on all assets. This provides results broadly consistent with the approach previously used by the Fund, whereby local currency returns are considered for each asset. This analysis produces the following risk premia relative to cash (shown on a scale from 1 to 15 with 1 being the highest expected return and 15 being the lowest):

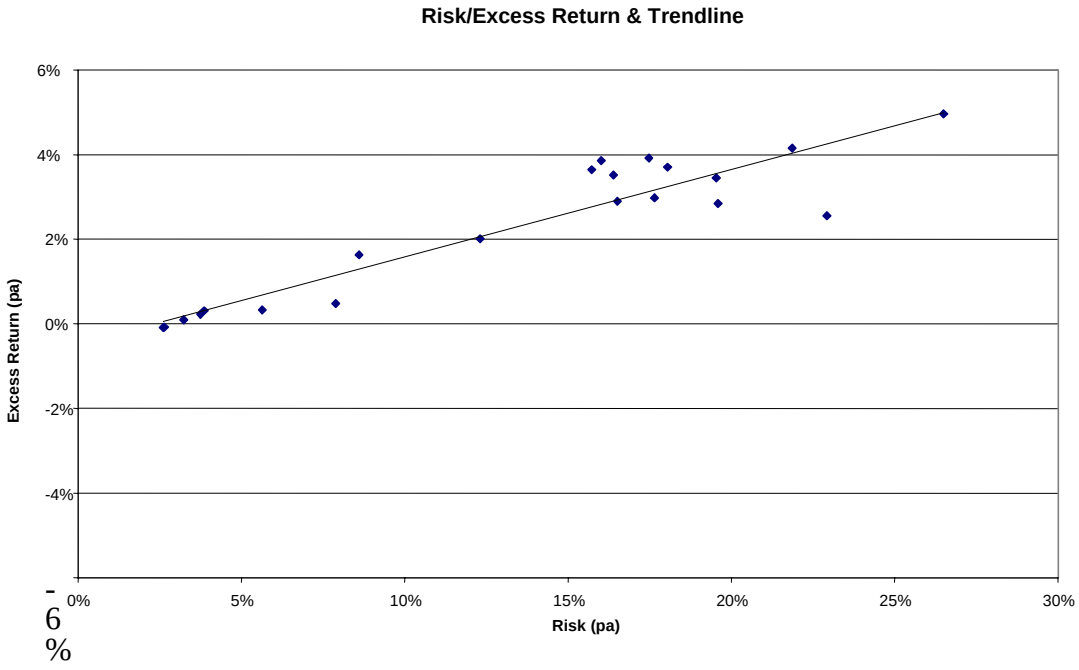
Asset Class	Expected Return (% pa)
US Equity	3
Canadian Equity	4
Europe Equity	5
Japan Equity	7
Far East ex Japan Equity	2
Emerging Market Equity	1
World ex US Government Bonds	12
US Government Bonds	12
US non-Government Bonds	11
Canadian non- Government Bonds	13
European non-Government Bonds	15
Japanese Non-Government Bonds	15
Australian Non- Government Bonds	14

Asset Class	Expected Return (% pa)
Global Property	9
Global High Yield	10
Global Emerging Market Debt (Sovereign)	6
Total	8

6.4 It will be seen that the returns for non-government debt are anomalously low, but otherwise the relative ranking of expected returns is not unreasonable. A common assumption in asset allocation models that lack such calibration is that the expected returns on all equity assets are the same. Our approach reveals that the expected excess returns are close, but not identical, and by construction, use of these slightly different expected excess returns reproduces market portfolio weights in the optimal asset allocation.

6.5 The anomalous results for non-Government debt are a consequence of a well known effect whereby non-Government debt appears to have a lower volatility of return than Government debt (in our calibration this is partly a function of the data periods available for the respective assets). Of course if it is believed that the returns on non-government debt are actually anomalously high then this adjustment can be criticised. However, on the more plausible assumption that the returns on corporate bonds are non-normal, this adjustment would appear to be more desirable than using prospective (or historic) estimates of expected return to argue for excess allocations to non-Government debt without allowing for non normality of returns. Some of the issues associated with modelling corporate debt are discussed in Exley & Smith (2002).

6.6 Another reasonableness check for these results is the simple regression of risk against the calculated excess return, as shown below.



6.7 Ranking the Contribution to Diversification

We can now use this model to rank the diversification benefit gained by including various asset classes. This aims to address one of the criticisms of the approach discussed in Section 3, namely that the diversification benefits of some asset classes are vanishingly small. More importantly, it gives us a theoretical framework for deciding on whether to include one asset class and reject another.

6.8 Ideally all excluded assets will fall below a certain score (expressed as a loss of expected return on the asset) and all included assets will fall above this score. However, this is an over simplification for a number of reasons:

i. Although we assume, implicitly, that all returns are net of average asset management fees, some assets will have additional implicit expenses for the fund that may rule out inclusion – such as additional monitoring expenses or lack of transparency. We concede that it is difficult to directly compare these qualitative "costs" with the quantitative basis of our ranking.

ii. It may be found that US corporate bonds are worth including, but Canadian corporate bonds are not, in isolation. However, when combined as "North American" corporate bonds both may merit inclusion. This shows that the ranking is just a tool and needs some basic rationale for the sub classification – between US and Canadian bonds for example. We

would suggest that an asset should be considered separately if it requires separate management, reporting etc.

6.9 It should also be noted that the analysis refers to the ranking of removing single assets. Clearly as more assets are removed the marginal benefit of the second, third, fourth assets in diversification terms will generally be found to be higher.

Sensitivity Testing to Historical Data Period

6.10 Our ranking of the various asset classes in terms of diversification benefit depends on the assumed volatility and correlation of the various asset classes, which we have derived from the longest available periods of data. In order to test the sensitivity of the results to these assumptions we have re-run the analysis using only the most recent five years of data. It should be noted that the analysis is of no relevance in the case of Global High Yield and European, Japanese and Canadian non Government bonds as this data is in any event limited to only five years of history. However, the dominant term in the calculation of the ranking of these assets is likely to be the low market capitalisation weight. Overall, the results show a similar pattern also over this period – particularly in relation to emerging market equity, small cap equity and real estate (the specific rankings change but the general positioning does not).

Application to Non-Market Capitalised Portfolios

6.11 Although the strict mathematical justification for this analysis breaks down for non market weighted benchmarks, if a portfolio is broadly similar to a market characteristics) then the above rankings are still likely to provide a reasonable indication of diversification benefit for the smaller asset classes. This is because the main driver for the diversification benefit is the correlation (or lack of correlation) with the major asset classes, which should be broadly similar in both cases.

Qualitative Considerations in the Inclusion of Asset Classes

6.12 Separate analysis provided to the Ministry cover in detail the practical and investment considerations of a number of the asset classes included in the preceding analysis: global small cap equity, real estate and emerging market debt. The broad conclusions of those reviews are set out below. Comments on private equity and inflation-linked bonds follow.

- We have already said that we see a clear case for the extension of the equity benchmarks to include **Small Cap Equity** (with the possible exception of Far East ex Japan equity) and our qualitative assessment of this asset class does nothing to undermine this conclusion. It is important to emphasise that this view does not depend upon the existence or otherwise of what is called the “Small Cap Effect” (that small cap can be

expected to outperform larger capitalization stocks and that this excess return is not readily accounted for by excess risk). The analysis given in this Section implicitly assumes that excess risk-adjusted returns are not available from any asset class.

- We have argued for the quantitative case of including **Real Estate** but the qualitative case is more equivocal. The easiest means of gaining exposure, via Real Estate Investment Trusts, is unlikely to offer a diversified global exposure (it will be principally US and UK), may be tax inefficient and the Fund is likely to need to acquire a significant share of the market to gain a 5% exposure with a market cap portfolio. Direct holdings of real estate could solve all these problems, but may introduce other more significant ones.

- The principal argument against **Emerging Market Debt** is the one resulting from our analysis above: that it contributes little to the portfolio, given its low market cap weight. Aside from that, it poses few particular problems, provided the issuers are acceptable and the Fund is prepared to permit exposure to lower credit quality issues.

Private Equity

6.13 Although no reliable data is available that would permit us to include private equity in our numerical analysis, the results for the above assets suggest that it is also unlikely that private equity will make a significant contribution to the risk profile. The potential difficulties in gaining initial exposure and subsequently managing it, in particular in terms of the general aim of operating the Fund on a transparent basis, would tend to argue against its inclusion in practice.

Inflation Linked Bonds

6.14 Taken at face value as a risky asset within a global market capitalisation weighted portfolio, inflation linked bonds are an unexceptional and small asset class (around 0.75% of total global financial assets).

6.15 The lower volatility of real interest rates relative to nominal rates tends to give inflation linked bonds a lower absolute volatility than nominal bonds and suggests a lower return premium.

6.16 Although excluded from the above quantitative analysis due to shortage of data, it is clear that since the market capitalised allocation is negligibly small and the risk characteristics muted, inclusion of the asset at this weight will have no material impact on risk characteristics of the market portfolio.

6.17 The more significant potential role for this asset is as a component of a possible least risk “satellite”, which we discuss in the final section of this report.

7

Consideration of a Least Risk Satellite Portfolio

The Satellite Portfolio Concept

7.1 The previous sections have been concerned with the asset allocation of the "core" portfolio of global financial assets, for which we recommend a market capitalisation weighted portfolio, subject to tests of materiality for minor asset classes.

7.2 However, we commented in section 2 that although the objectives of the Fund did not give firm guidance on the "acceptable" level of risk, the current strategy, with 40% equities implied a certain risk tolerance. In section 4 we suggested that the market capitalised portfolio has an effective equity exposure (as at end November 2002) of around 15% more than the current strategy (after due allowance for the equity characteristics of Real Estate, Emerging Market Debt and High Yield).

7.3 Thus in simple terms, to restore equity exposure down to 40%, a "least risk" bond satellite portfolio of around 25% of the total fund would need to be constructed. (We suggest for practical purposes ignoring the minor equity allocation in the theoretical least risk portfolio allocation for this purpose). The remaining 75% of the portfolio would be allocated to a global market capitalisation weighted benchmark.

7.4 This assumes that the existing 40% equity allocation is maintained. The possibility of holding only the core benchmark portfolio could of course be considered. Indeed the results in previous sections suggest relatively modest reductions in risk associated with reducing the equity allocation at these levels of exposure.

7.5 If we follow the principles of the rest of this report then the natural starting point would thus be the market capitalisation weighted portfolio of long dated index linked Government bonds from all of the issuing countries. However, once we overweight this asset class beyond its global market weights (potentially by a factor of 30x) the concentration of this portfolio in particular economies and in particular currencies does become a concern.

7.6 The currency concentration of these bonds should be addressed by modifying the currency exposure back to consumption based weights using currency hedging.

7.7 The concentration in particular economies (and in relatively small markets within economies) and exposures within economies that do not issue this form of debt should be addressed by using a proxy for inflation linked bonds.

Inflation Linked Proxies.

7.8 As discussed in Section 2, analysis of the extensive UK data on inflation linked bonds shows that conventional bonds actually provide the next best proxy for matching an inflation linked liability.

7.9 For example based on the past five years of data for the UK the optimal portfolio to hedge long term inflation linked liabilities (in the absence of inflation linked bonds) would allocate only around 3% to equities with the remainder in nominal bonds. For an economy with inflation (expectation) volatility similar to that in the UK, the duration of the bond portfolio would be around one third of the duration of the real liability being hedged.

Combined Strategy

7.10 Thus, we are recommending that any least risk "satellite" strategy should consist of an aggregate benchmark of inflation linked bonds in those economies issuing these bonds combined with a portfolio of 10 year maturity bonds in those economies that do not issue inflation linked. There is less justification for "market weights" of economies in these portfolios. We would recommend that economy weights for this satellite portfolio are based on import weights.

7.11 In view of the size and liquidity of the global inflation-linked market, we would recommend that in practice a maximum of only 3% of any inflation linked market be held by the Fund in inflation-linked bonds. Where this limit is exceeded, the conventional bond proxy should be adopted even in economies issuing inflation linked bonds.

Conclusions

7.12 There is uncertainty in the definition of the Fund's liabilities. The least risk strategy depends crucially on the choice of currency weights and the choice of

(implicit) duration of the liabilities. Even where these two parameters can be identified, it seems likely that second of these will be well beyond the duration of deep markets in inflation linked bonds for a Fund this size. For economies without inflation linked bonds, there is a substantial residual risk associated with attempting to hedge long dated inflation linked (implicit) liabilities with conventional bonds.

7.13 Our overall conclusion is that the satellite portfolio is likely to be only a weak proxy for the implicit liabilities. Nevertheless, it provides a rational mechanism for reducing risk in the core portfolio if required.

Appendix A

Table of Covariance Matrix

	US Large Cap Equity	Canadian Large Cap Equity	Europe Large Cap Equity	Japan Large Cap Equity	Far East ex Japan Large Cap Equity	Emerging Market Equity	World ex US Government Bonds	US Government Bonds	US Small Cap Equity	Canada Small Cap Equity
US Large Cap Equity	0.025661247	0.021745256	0.017884654	0.010165091	0.0211892	0.022540671	0.001282133	0.000639146	0.021995743	0.014487984
Canadian Large Cap Equity	0.021745256	0.032577246	0.018181073	0.010661693	0.025179436	0.022932769	0.001129025	0.000637483	0.021525515	0.020925823
Europe Large Cap Equity	0.017884654	0.018181073	0.024719848	0.012876151	0.022426928	0.02676246	0.001331129	-6.13407E-05	0.01992048	0.015084307
Japan Large Cap Equity	0.010165091	0.010661693	0.012876151	0.038383291	0.012455593	0.020998896	0.00139965	0.001129919	0.014615193	0.013269484
Far East ex Japan Large Cap Equity	0.0211892	0.025179436	0.022426928	0.012455593	0.047803461	0.034385975	0.000682379	0.000816952	0.021007985	0.018105322
Emerging Market Equity	0.022540671	0.022932769	0.02676246	0.020998896	0.034385975	0.070238108	0.000721196	0.00035139	0.028541038	0.024359662
World ex US Government Bonds	0.001282133	0.001129025	0.001331129	0.00139965	0.000682379	0.000721196	0.001492746	0.000174493	0.000781686	0.000275434
US Government Bonds	0.000639146	0.000637483	-6.13407E-05	0.001129919	0.000816952	0.00035139	0.000174493	0.00317777	-0.000220567	-0.00040458
US Small Cap Equity	0.021995743	0.021525515	0.01992048	0.014615193	0.021007985	0.028541038	0.000781686	-0.000220567	0.030544706	0.022198219
Canada Small Cap Equity	0.014487984	0.020925823	0.015084307	0.013269484	0.018105322	0.024359662	0.000275434	-0.00040458	0.022198219	0.027264883
Europe Small Cap Equity	0.015996942	0.01699617	0.024222375	0.016454084	0.020338585	0.029751271	0.000722451	-0.000305931	0.019909398	0.016828712
Japan Small Cap Equity	0.008297738	0.009903771	0.012369553	0.04145087	0.012782527	0.01698524	0.000384463	0.001581675	0.009776112	0.011107066
Far East (ex Japan) Small Cap Equity	0.015891457	0.018193865	0.017482193	0.015243983	0.034834323	0.035611704	0.001340323	0.000270974	0.019729778	0.017745211
US non-Government Bonds	0.000835042	0.000708778	0.00011081	0.001600119	0.00100884	0.000634129	0.000177892	0.004095207	-8.72889E-05	-0.000425749
Canadian non-Government Bonds	0.00122175	0.001924321	0.00023592	0.000760708	0.000749605	0.000806136	0.0004931	4.50838E-05	0.001904461	0.002124816
European non-Government Bonds	-0.000606653	-0.000926659	-0.000952214	-0.000828725	-1.07043E-05	-0.001331171	0.000528932	4.67012E-05	-0.000928047	-0.001275246
Japanese Non-Government Bonds	-0.000858462	-0.000492399	-0.00069268	-0.000193933	-0.000174956	-0.000319853	0.000251943	6.10316E-05	-0.000897913	-0.000271308
Australian Non-Government Bonds	0.00032262	0.001078378	-0.000208789	-2.2696E-05	0.000687772	6.60728E-05	0.000442773	5.6121E-05	0.000918642	0.00128725
Global Property	0.010891627	0.012096137	0.009478896	0.004976347	0.0127604	0.009392064	0.001510927	0.000548618	0.009693916	0.007077682
Global High Yield	0.00831942	0.009478945	0.008548052	0.007228151	0.008174009	0.0150609	-6.58251E-05	-3.97589E-05	0.011341094	0.009689032
Global Emerging Market Debt (Sovereign)	0.014580761	0.018103196	0.014826792	0.01437646	0.019905854	0.031383325	0.000826844	0.00025547	0.017172428	0.015882963

	Europe Small Cap Equity	Japan Small Cap Equity	Far East (ex Japan) Small Cap Equity	US non-Government Bonds	Canadian non-Government Bonds	European non-Government Bonds	Japanese Non-Government Bonds	Australian Non-Government Bonds	Global Property	Global High Yield	Global Emerging Market Debt (Sovereign)
US Large Cap Equity	0.015996942	0.008297738	0.015891457	0.000835042	0.00122175	-0.000606653	-0.000858462	0.00032262	0.010891627	0.00831942	0.014580761
Canadian Large Cap Equity	0.01699617	0.009903771	0.018193865	0.000708778	0.001924321	-0.000926659	-0.000492399	0.001078378	0.012096137	0.009478945	0.018103196
Europe Large Cap Equity	0.024222375	0.012369553	0.017482193	0.00011081	0.00023592	-0.000952214	-0.00069268	-0.000208789	0.009478896	0.008548052	0.014826792
Japan Large Cap Equity	0.016454084	0.04145087	0.015243983	0.001600119	0.000760708	-0.000828725	-0.000193933	-2.2696E-05	0.004976347	0.007228151	0.01437646
Far East ex Japan Large Cap Equity	0.020338585	0.012782527	0.034834323	0.00100884	0.000749605	-1.07043E-05	-0.000174956	0.000687772	0.0127604	0.008174009	0.019905854
Emerging Market Equity	0.029751271	0.01698524	0.035611704	0.000634129	0.000806136	-0.001331171	-0.000319853	6.60728E-05	0.009392064	0.0150609	0.031383325
World ex US Government Bonds	0.000722451	0.000384463	0.001340323	0.000177892	0.0004931	0.000528932	0.000251943	0.000442773	0.001510927	-6.58251E-05	0.000826844
US Government Bonds	-0.000305931	0.001581675	0.000270974	0.004095207	4.50838E-05	4.67012E-05	6.10316E-05	5.6121E-05	0.000548618	-3.97589E-05	0.00025547
US Small Cap Equity	0.019909398	0.009776112	0.019729778	-8.72889E-05	0.001904461	-0.000928047	-0.000897913	0.000918642	0.009693916	0.011341094	0.017172428
Canada Small Cap Equity	0.016828712	0.011107066	0.017745211	-0.000425749	0.002124816	-0.001275246	-0.000271308	0.00128725	0.007077682	0.009689032	0.015882963
Europe Small Cap Equity	0.026866835	0.014698153	0.018152278	-0.000127806	0.000217883	-0.001137233	-0.000364915	-0.000489986	0.007046911	0.01120438	0.014253485
Japan Small Cap Equity	0.014698153	0.05255377	0.012318571	0.001533321	0.001438227	-0.0003717	-0.000165383	0.000335747	0.003387357	0.005267032	0.00733551
Far East (ex Japan) Small Cap Equity	0.018152278	0.012318571	0.038173512	0.00033123	0.000928857	-0.000101612	0.000290021	0.000804216	0.008531374	0.00720259	0.021033739
US non-Government Bonds	-0.000127806	0.001533321	0.00033123	0.006216332	6.68401E-05	4.45865E-05	8.2468E-05	6.47199E-05	0.000735325	-3.93424E-05	0.000428886
Canadian non-Government Bonds	0.000217883	0.001438227	0.000928857	6.68401E-05	0.001402911	0.000549135	-2.25514E-05	0.000853361	0.000817285	0.000886136	0.002536192
European non-Government Bonds	-0.001137233	-0.0003717	-0.000101612	4.45865E-05	0.000549135	0.000676263	-3.91636E-06	0.00041461	0.000293079	0.000132773	-0.000183935
Japanese Non-Government Bonds	-0.000364915	-0.000165383	0.000290021	8.2468E-05	-2.25514E-05	-3.91636E-06	0.000697117	0.000169086	0.00058234	-9.24781E-07	6.03702E-05
Australian Non-Government Bonds	-0.000489986	0.000335747	0.000804216	6.47199E-05	0.000853361	0.00041461	0.000169086	0.001044746	0.001065711	0.000195592	0.002118111
Global Property	0.007046911	0.003387357	0.008531374	0.000735325	0.000817285	0.000293079	0.00058234	0.001065711	0.015155605	0.00335254	0.007975982
Global High Yield	0.01120438	0.005267032	0.00720259	-3.93424E-05	0.000886136	0.000132773	-9.24781E-07	0.000195592	0.00335254	0.007396017	0.008564286
Global Emerging Market Debt (Sovereign)	0.014253485	0.00733551	0.021033739	0.000428886	0.002536192	-0.000183935	6.03702E-05	0.002118111	0.007975982	0.008564286	0.0311519

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