BI Norwegian Business School - campus Oslo

GRA 19703

Master Thesis

Thesis Master of Science

IS THE "HANDLING REGLER" SUSTAINABLE IN THE LONG RUN? RETURN UNCERTAINTY, PAYOUT RULES, AND SURVIVAL OF THE NORWEGIAN PENSION FUND GLOBAL

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Start: 15.01.2019 09.00

Finish: 01.07.2019 12.00

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Abstract

The Norwegian Government Pension Fund Global enjoys the position of being one of the largest global sovereign funds in line with Abu Dhabi Investment Authority, China Investment Corporation and Saudi Arabian Authority with accumulated assets of more than $1 trillion. However, miraculous its depletion may look, this issue is already attracting attention as its first payouts to the National Budget started in 2016, so that given stable but unsustainable payout rate, the Fund, created to provide perpetual benefit to Norwegian generations, may be depleted within much limited timeframe. The current payout rule or handling regler was set at the level of 3 percent and linked to expected real returns on the Fund's portfolio that are currently estimated at above 3% y-o-y, but these expectations are subject to mistake and bias. This paper argues that given the Fund's goal to preserve the purchasing power of its endowment, the payout rate must be strictly below the average expected return on the Fund for two reasons: *(i)* if returns are variable, the rate of the Fund's growth will be less than the average expected return, and *(ii)* asset returns demonstrate long cycles over long horizons, with extended period of average returns below the long-term average. Given an expected real rate of return after management costs of 3.6%, based on historical simulations, we believe that the current Fixed 3% payout rule is sustainable because it effectively protects the Fund's corpus in the long run. However, if the ability to ensure stable and slightly countercyclical payouts is of great importance, the Average payout rule is a viable alternative.

1 Introduction

Norway is widely considered to be one of the wealthiest countries in the world due to its rich deposits of natural resources. In particular, large oil and gas reserves discovered in the North Sea in the late sixties have contributed significantly to economic growth of the country, and to the financing of the Norwegian welfare state. Norway's petroleum revenue management is reflected in its Sovereign Wealth Fund, the so-called Government Pension Fund Global (GPFG), a fiscal policy tool aimed at keeping macroeconomic stability and intergenerational distribution of petroleum wealth. Faced with the biggest oil and gas price fall in 30 years, in January 2016, Norway made its first withdrawal of 6.7 billion Norwegian Kroner (NOK) from the GPFG, exactly 20 years after first cash deposit from its vast oil sector into the Fund. The sharp increase in the annual budget spending was primarily attributed to an economic downturn triggered by falling oil industry revenues as the price of North Sea crude has fallen by about 70 percent since mid-2014. The instability of oil prices along with increasing pressure caused by the depletion of natural resources have raised the necessity to investigate the sustainable future payout policy given the Fund's purpose and objectives.

The Fund is an integrated part of the state's annual budget. Its capital comes from total government oil revenue, net financial transactions associated with oil activities, net the amount spent to meet the state's non-oil budget deficit. The Fund therefore operates as a fully integrated part of the state annual budget, with the structural, non-oil budget deficit corresponding to the expected real return on the Fund, currently estimated at 3 percent. That is, the bigger the Fund becomes, the larger the transfer, and the larger the sustainable non-oil deficit. Since the first deposit of approximately 2 billion NOK in 1996, the Fund has experienced growth mainly due to large financial deposits. The GPFG has thus become global largest publicly owned fund, with the market value of 8'461 billion NOK as of December 2018.

As one of the largest sovereign wealth funds, GPFG faces heightened attention due to its both sheer size and rather mediocre performance since inception.

Often contrasted to Yale's endowment with highly activist position and appetite towards illiquid alternative investments, Norwegian Fund was criticized of squandering advantages because of its bureaucracy and too passive stance. Nevertheless, the Fund effectively shielded the Norwegian economy from "the Dutch disease" and started to increase gradually the share of equity and non-listed real estate investments in the portfolio. Today, the Fund invests in international equity (66.8%), fixed-income markets (30.6%) and unlisted real estate (2.6%). Such gradual shift to alpha investing additionally raises uncertainty about average long-term growth of the Fund and the payout rate that would not obstruct the growth potential.

In general, the GPFG pursues one major goal: to ensure responsible and long-term management of petroleum industry revenue so that the capital benefits both current and future generations of Norway. Achieving the former task directly relates to periodic withdrawals to support government's spending, still the level of such withdrawals influences in turn the Fund's performance and capacity. Because of the infinite investment horizon of the Fund, the obvious solution is to target fixed proportion of the Fund's portfolio, but it leads to pro-cyclical withdrawals that are higher when the economy is going up and lower when the economy is slowing down. This is not exactly what is desirable by sovereigns, who want stable and slightly countercyclical payouts. Thus, if the Fund does not carefully estimate its spending rule, there is apparent risk of exhausting financial resources before their intended maturity. This discrepancy as well as forecasted depletion of oil resources provide the motivation to estimate the payout policy that would enable Norway to mitigate the danger of endowment's value loss while ensuring total social spending.

Given the Fund's goal and objectives, the average payout rate must be below the average expected return on the Fund for two reasons: *(i)* if returns are variable, the rate of the Fund's growth will be less than the average expected return, and *(ii)* asset returns demonstrate long cycles over long horizons, with both extended period of average returns below and above the long-term average. Therefore, the first research question targeted in this paper seeks to investigate the sustainability and performance of the current 3% Fixed payout rule. And the second ambition is to compare such performance of current rule to several alternative spending policies. The question of how the government makes use of the Fund, though important, is beyond the scope of this study.

Main methods to be used are finding the analytical solution through withdrawals' model creation and subsequent statistical simulations. Specifically, reasonable approach would include a combination of stochastic model of predictive returns over a long-time horizon with a deterministic model of particular payout rule. Data to be employed consists of a wide range of historical macroeconomic measures and forecasts along with financial position of the Norwegian sovereign wealth fund. The thesis paper consists of ten sections. Sections 2 – 4 will set the stage and overview of the paper, as well as review the existing academic and professional literature on the topic. The formal structure, research tools, and data will be discussed in sections 5 and 6. Sections 7 – 9 describe the empirical methods and results in relation to the research questions, and Section 10 summarizes the investigated issue.

2 Government Pension Fund Global: Function, Obligations, Governance

2.1 Functions of the GPFG

Commenced in the early 1970s, Norway's oil industry brought many challenges to the government in ensuring a sustainable economic development. The public revenues from oil industry are large, volatile, and expected to be depleted over time. Moreover, in accordance with ethical considerations, income from non-renewable resources like oil and gas should benefit equally present and future generations. The establishment of the Government Pension Fund Global (GPFG) and the fiscal rule for the use of oil and Fund revenue was an attempt to address these challenges through a long-term policy.

Overall, the most important functions of the GPFG relate to its role in: *(i)* stabilization of key macroeconomic variables, and *(ii)* the long-term investment of accumulated public savings.

(i) The former function is particularly important in resource-rich countries like Norway because of economic uncertainties related to natural resource exploitation: oil and gas prices are highly volatile, whereas production levels and the value of reserves are difficult to forecast over the long term. Furthermore, Norway has made an explicit reference to the role of the Fund in preventing “the Dutch disease”, the economic concept explaining a loss of export competitiveness and a resulting fall in the manufacturing industries caused by the development of a specific sector, in this case, – petroleum industry (Van Wijnbergen, 1981; Corden & Neary, 1982). To combat the “resource curse”, a large portion of accumulated savings from oil industry is invested abroad in order to protect the national currency against appreciation generated by the large foreign exchange earnings from export of petroleum products.

(ii) The other goal of the GPFG is to maintain the purchasing power of its

endowment and generate enough income to finance the non-oil deficit. This is done through long-term investment plans that involve portfolio diversification to enhance expected returns. One of the leading factors driving the saving of the Fund's value is related to ethical concept of the intergenerational distribution of wealth between present and future generations. That is, each generation secures a fair amount of the endowment for generations to come, while using the Fund's capital to finance its own activities to an appropriate extent (Dyachkova, 2015). Other important factors include prudence around the depleting public source of wealth and economic concerns around the ability to absorb large cash flows coming from export of petroleum products(Alsweilem, Cummine, Reitveld, & Tweedie, 2015). It is worth mentioning that, despite its name, the GPFG does not have any formal pension liabilities. Thus, the likelihood of large withdrawals from the endowment is restricted, making the GPFG truly long-term.

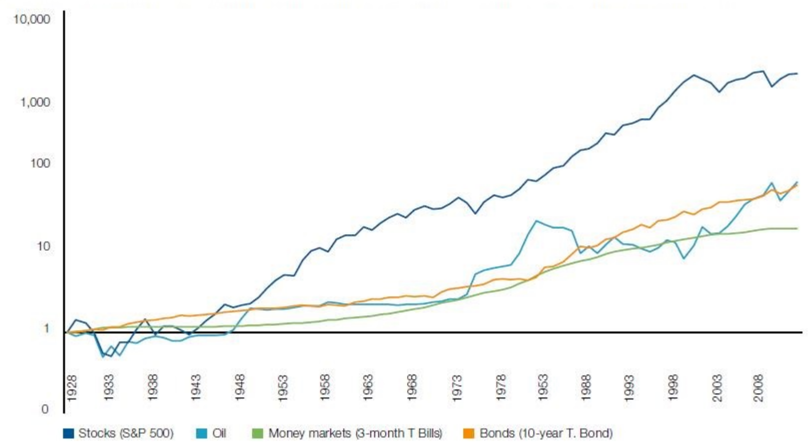
Both primary functions of the GPFG – stabilization and savings investment – might be understood as part of a process of transforming a depleting asset base (natural resources) into a permanent one (an endowment of financial assets). The general faith in financial assets as a source of a higher risk-adjusted return compared to natural assets can explain the decision to transform the income source from commodities to financial assets (the historical outperformance of financial assets over oil is shown in Figure 2.2[1]. Knut Kjaer, the former head of the GPFG, emphasized this argument in his speech (2006): “Oil price volatility has historically been far larger than the variations in the return on equities and fixed-income instruments”(Figure 2.1)[2].

[1]Bloomberg and US Energy Information Agency (2006)
[2]Note: the chart shows VaR calculation as of 2006 (Kjaer, 2006)

Figure 2.1. *Stabilization – value-at-risk of Norway's financial versus oil assets*

The establishment of the GPFG was also guided by politico-economic dynamics. There is a wealth of evidence showing that the level of public spending and investment decisions degenerates in the periods of sharp increases in public wealth (Gelb, Tordo, Halland, Arfaa, & Smith, 2014). Following a clear, rule-based system, the GPFG increases the horizon over which revenue windfalls are spent and invested in the domestic economy, thereby potentially improving political incentives and reducing the declining returns on public investment over the short-term (Robinson, Verdier, & Torvik, 2006).

Figure 2.2. *Wealth transformation – growth in the value of $1 of financial assets and oil, 1928 - 2005*

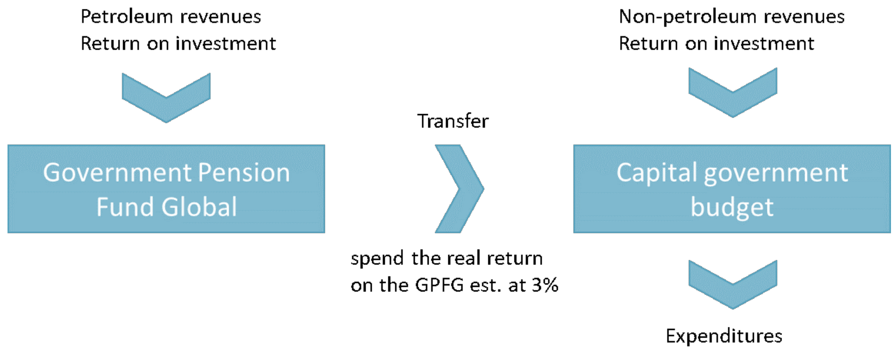


2.2 Payout rule

In 2001, Norway introduced a new payout framework that supplemented the GPFG with an explicit fiscal rule, intended to *(i)* make the use of oil revenues more transparent, *(ii)* strengthen the decoupling of petroleum revenue use from revenue inflow, and *(iii)* ensure an appropriate long-term allocation of oil revenue.

Formally, the GPFG can be viewed as a government account held with the central bank. The primary source of the Fund's inflow comprises net cash flow from petroleum activities, such as taxes and royalties generated from the extraction of oil and gas, and the direct returns from the Fund's investments. The Fund also manages net revenues from the government's sale of share in Equinor, the national oil company, and other government equity in the sector. The Fund's outflow, in turn, comprises transfers to the government budget to cover capital and recurrent expenditures, represented by the non-oil deficit (Figure 2.3[3]).

Figure 2.3. *The relationship between the GPFG and the fiscal budget*



Oil wealth is phased into the economy by transferring all returns from sales and investments to the GPFG. The government can spend, on average over the cycle, its real return, estimated at 3 percent presently

[3]Source: Regjeringen (n.d.)

This payout framework was described by Olav Bjerkholt and Irene Niculescu (2004) as being based on a "bird-in-the-hand" approach, where the so-called liquidated resource wealth accumulated in the Fund regulates the use of petroleum revenues. Following this framework, the total revenue can be split into two types based on its source: petroleum-related R_1 and the rest revenues R_2; similarly, total expenditures are divided into petroleum-related expenditure C_1 and the rest expenditures C_2. The overall surplus S is thus:

$$S = R_1 + R_2 - C_1 - C_2 \tag{1}$$

From the above-equation, we can then derive the non-oil deficit D_2 is

$$D_2 = C_2 - R_2 = R_1 - C_1 - S \tag{2}$$

Further, we can formulate the value of endowment F_t, established at $t = 0$, by the following equation:

$$F_t = (1 + r_{t-1}) * F_{t-1} + (R_{1,t-1} - C_{1,t-1}) - D_{2,t-1} \tag{3}$$

where r_{t-1} is the real return on the Fund's capital in the period t - *1*.

In addition, to decouple the petroleum revenues and ensure moderate phase-in, the fiscal rule stipulates that the target for the non-oil deficit shall be equal to the expected real return on the fund at $t = 0$:

$$D_{2,t*} = r_t * F_t \tag{4}$$

where r_t is correspondingly the expected real rate of return on the fund in the period t.

Due to the last condition, the volatile nature of the commodity prices and other macroeconomic variables effectively become negligible. Therefore, despite its conservative approach, the rule can accommodate both explicit and implicit future fiscal commitments that increase over time.

However, Bjerkholt and Niculescu point out that this approach yet has a serious drawback: it ignores the cyclicality and the risk of unanticipated changes in the real return on the fund. Therefore, a modified rule, adjusted to cyclical fluctuations and uncertainty in the returns, must be specified:

$$D_{2,t*} = r_{t*} * F_t \qquad (5)$$

where r_{t*} is the “adjusted” expected rate of return on the Fund portfolio.

Following the new approach, if any significant changes occur in the target deficit, say due to a fall in stock markets, the new approach will smooth out those changes over several years, based on an expected real rate of return on the fund a few years ahead.

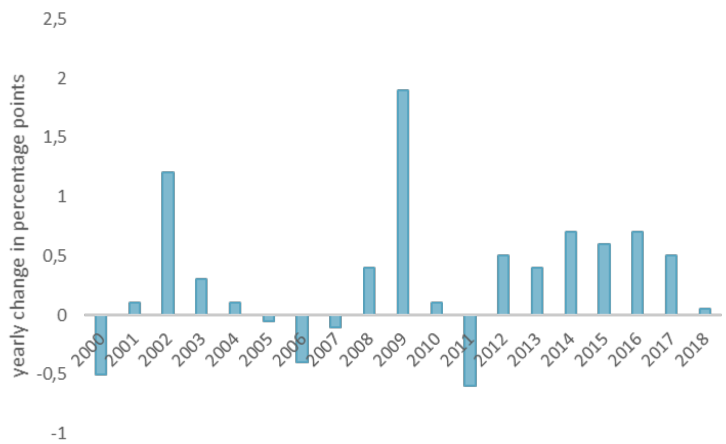
Although considered by many economists as well-designed, the Norwegian fiscal rule yet is not ideal. Currently, the rule links the non-oil deficit to the Fund's capital but does not relate it to GDP (International Monetary Fund, 2013). If the Fund grows more rapidly relative to the economy over several years, the non-oil deficit will simultaneously grow as a share of GDP. The reverse is also true. Given that, over the long horizons it may be increasingly difficult to prevent increases in public expenditures for laudable purposes above and beyond, especially during a prolonged period of high oil prices and/or high returns on the assets accumulated in the Fund.

As it is well illustrated in the National Budget of 2018, petroleum revenue spending has been expanded considerably since the fiscal rule was introduced in 2001 (Figure 2.4[4]). However, with petroleum prices around the present level [5] and gradually declining production in the North Sea, the new capital inflow

[4]Source: National Budget 2018
[5]Crude Brent – USD 66.5 (June 28, 2019)

to the fund is forecasted to be lower than Norway has become accustomed to (Figure 2.5[6]). Furthermore, the expected real return on endowment was estimated to fall from 4% to 3% in the long run. Therefore, the scope for further expansion of oil revenue spending is limited, so the government of Norway must decide if and how it will sustain the level of today's petroleum revenue spending in the future.

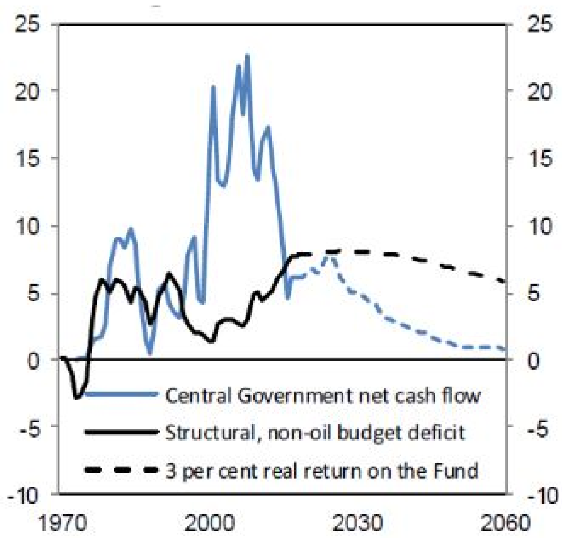
Figure 2.4. *Structural, non-oil budget deficit. Percent of trend GDP Mainland Norway*



The Norwegian economy and welfare system, hence, strongly depend on the management of the GPFG and the payout rule specifying how much of the endowment can be consumed today. If the payouts from the Fund are too high, the current endowment might be depleted in much more deterministic way. When looking long-term, the pressure on public finances becomes even more severe. An aging population means that a smaller proportion of the population would be working and paying tax, whilst expenditure on pensions, as well as on health and care services, is going to rise. Hence, the possibility for fiscal policy "maneuvers" seems to be much lower over the next 10-15 years (National Budget, 2018). Revenues need to be increased, or expenditures must be reduced.

[6]Source: National Budget 2018

Figure 2.5. *Norway's net cash flow from petroleum activities*[7]



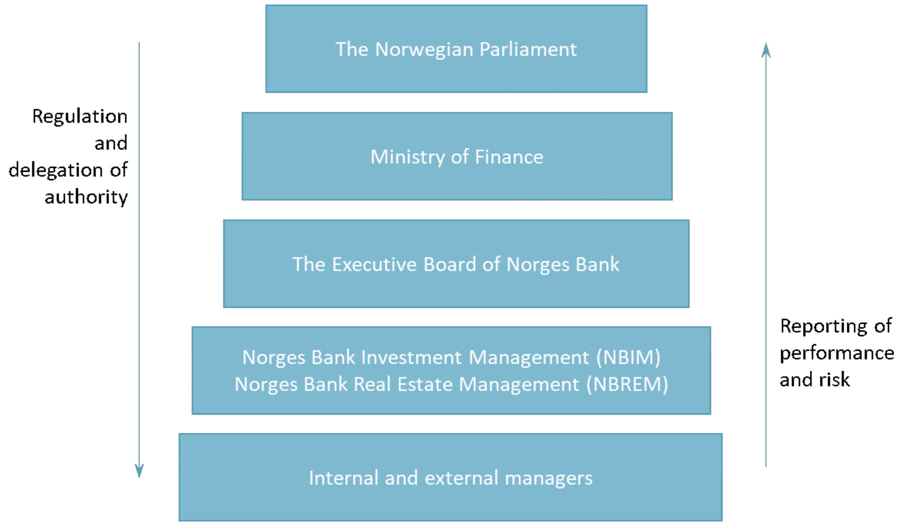
2.3 Governance model

The payout rule is not legally binding, but rather determined by a broad political and public consensus supported by inter-institutional approach to managing the GPFG. The Ministry of Finance, the Parliament, and the Central Bank clearly divided roles and responsibilities in overseeing the sovereign fund, following strict reporting and disclosure requirements.

The governance structure of the Fund is built in a way that delegates tasks and authority downwards in the system, while performance and risk factors are reported upwards (Figure 2.6[8]). Each agent of the governance structure reports to its own supervisory unit and receives reports from its subordinate unit. The exception to this framework is that the Executive Board of Norges Bank is supervised by the Supervisory Council, a governing body appointed by the Storting, which also elects the Bank's external auditors.

[8]Source: Regjeringen.no (2018)

Figure 2.6. *Governance structure of the GPFG*[9]



In short, the distribution of core responsibilities and reporting lines around the GPFG are as follows (Natural Resource Funds, 2013):

- The Norwegian parliament passes legislation governing the Fund, confirms the yearly budget, assigns the Supervisory Council, and assesses reports on the Fund's strategy and performance prepared by the Ministry of Finance, the Fund's operational investment manager and auditors.

- The Ministry of Finance performs as Fund's owner (on behalf of citizens) and determines the Fund's broad strategy (as reflected in its Strategic Asset Allocation). The Ministry then delegates operational management to a devoted team within the Central Bank (Norges Bank), through a mandate that clearly states investment guidelines, ethical standards, risk and internal control.

- The executive board at Norges Bank serves as the Fund's operational manager. It further develops investment mandate in accordance with the strategy developed by the Ministry of Finance and establishes principles of risk and internal management for Norges Bank Investment Management (NBIM) unit.

- NBIM is a specialized asset management department within the Central Bank and is the operational fund manager of the GPFG. It implements investment strategy and performs the small degree of active management officially allowed by the Ministry of Finance.
- The Supervisory Council oversees the Norges Bank's operations. It has rightful access to information and reports its investigation results to the parliament.
- The General Auditor conducts an audit of the Fund's activities and reports the results to the parliament. In addition, an external auditor is appointed, which reports to the Supervisory Council.

3 Investment Universe

The Fund as of 2018 has invested in three areas: (*i*) Equities, (*ii*) Fixed income, (*iii*) Real estate – and is one of the most diversified across countries and industries worldwide. Simultaneously, the GPFG is forbidden to invest into Norwegian market to avoid overheating of the domestic economy.

3.1 *Geographical distribution*

The Fund's investment universe covers 70 countries in equity portion, 54 countries in fixed income, and 7 countries in real estate[10]. For the equity portfolio, the investment in each country well correlates with country's share in global market portfolio, with United States accounting for 39% of all equity investments, UK and Japan – 9%, Germany and France – around 5%, etc. Notably, most of Central Asian, Central American and African countries do not receive investment from the GPFG. Fixed income regional allocation is like the one of equity portfolio, with the USA share of 43%, Japan – 10%, Germany – 9%, UK, France and Canada – from 4% to 5%. Real Estate investments are the smallest in size with the USA and the United Kingdom totaling to 71% of the real estate portfolio. Detailed breakdown is illustrated in Appendix A.

3.2 *Investment type distribution*

There are 11 major categories for Equity investments: Financials (23,7%), Industrials (12,9%), Technology (12,6%), Consumer Goods (11,9%), Health Care (11,4%), Consumer Services (10,8%), Oil & Gas (5,9%), Basic Materials (5%), Telecommunications (3%), and Utilities (2,8%). Fixed income investments are predominantly allocated to Government and Government-related

[10]7 major countries, without considering "other" category that includes around 8 percent of the whole amount of real estate portfolio

bonds – 59,5% and 21,7% accordingly, while Corporate, Securitized, and Corporate/Securitized account for 21,8%, 3,2%, and 3,1% respectively (Appendix B). Real Estate investments are allocated to Retail, Logistics, and Office properties.

3.3 *Investment Strategy*

"Our investment strategies aim to exploit the Fund's characteristics as a large, global investor with limited short-term liquidity requirements in order to achieve a high return with acceptable risk" (NBIM, Annual Report 2017) Overall investment strategy is defined through a management mandate by the Ministry of Finance that specifies which markets the Fund can be invested in and sets limits for allocation to different asset classes. Particularly, the Fund has very long-term horizon and small short-term liquidity needs, so the strategy is built to benefit from these Fund's characteristics. The Fund must generate highest possible return (subject to the constraints set by the Ministry of Finance), while minimizing market risk through broad diversification. Current investment mandate was amended with effect from 1 January 2017 (Strategy 2017-2019), and the investment strategies can be grouped into three main categories: Fund allocation, Asset strategy, and Company investments.

3.3.1 *Fund allocation*

As a starting point for portfolio investments, the Fund refers to so-called reference portfolio which is more suitable for the needs of the fund than the benchmark index (strict benchmark for large funds leads to unnecessary friction costs). The purpose of using such reference portfolio is to obtain the best possible risk-return characteristics within the opportunity set, and when market movements lead to deviations from the reference, reallocations are made with consideration of changing risk profile and transaction costs. Worth to note that investments into real estate are done by selling Equities and Fixed income in the same currency. The Fund continues its market and industry expansion using systematic factor strategies to further enhance results and diversification.

3.3.2 *Asset strategy*

Asset positioning, securities lending and minimization of transaction costs are the tools for Fund's asset management. In terms of security lending, both direct internal lending and external agency lending are used to offer attractive lending terms. Fund's scale allows to effectively minimize transaction costs by benefiting from the liquidity needs of other smaller investors and capital market events. Risk is controlled at regional, sector, and issuer level.

3.3.3 *Security selection*

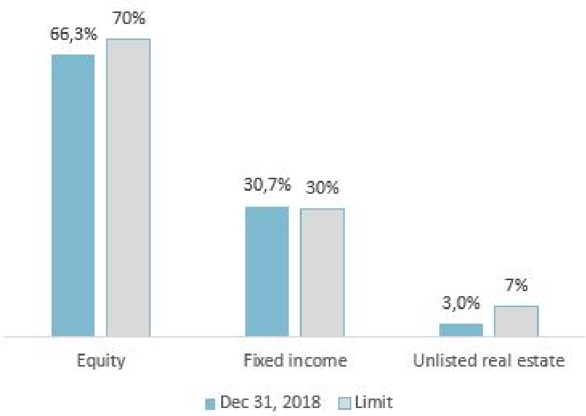
The Fund uses both internal and external security selection. The latter applied mostly to emerging markets where the Fund benefits from assistance of external managers as it has less available information about those markets. Generally, stock selection plays a smaller role than asset allocation in short-term, but given Fund's long-term horizon, underlying companies developments are crucial for understanding where market is moving and what returns to expect.

3.4 *Market Risk Management*

Most relevant risks for the Fund to look at are movements in stock prices, interest rates and exchange rates, with consideration of liquidity risks as well. Firstly, for the overall portfolio, the Ministry of Finance sets strategic benchmark index based on Bloomberg Barclays and FTSE Group indices with currently 37,5% allocation to Fixed income securities and 62.5% – to Equities.

The Fund's active management is aimed to achieve higher returns than the benchmark portfolio, which focuses on a passive investment strategy consisting of global indices. Through active management NBIM's target is to add a net value of around 25 basis points. Actual benchmark index is allowed to deviate from the strategic one by an expected relative volatility (tracking error) of 1,25% – that is how much the return on the Fund can be expected to deviate from the return on the benchmark index in a normal year. To predict future market volatility, expected tracking error uses historical data together with concentration and factor exposure analysis. Under the new model, investments into Equities cannot exceed 70% of the Fund market value, Fixed income – up to 30% and Real Estate – up to 7% (Figure 3.1)[11].

Figure 3.1. *Asset allocation (current vs. maximum allowed)*



[11] NBIM (2018)

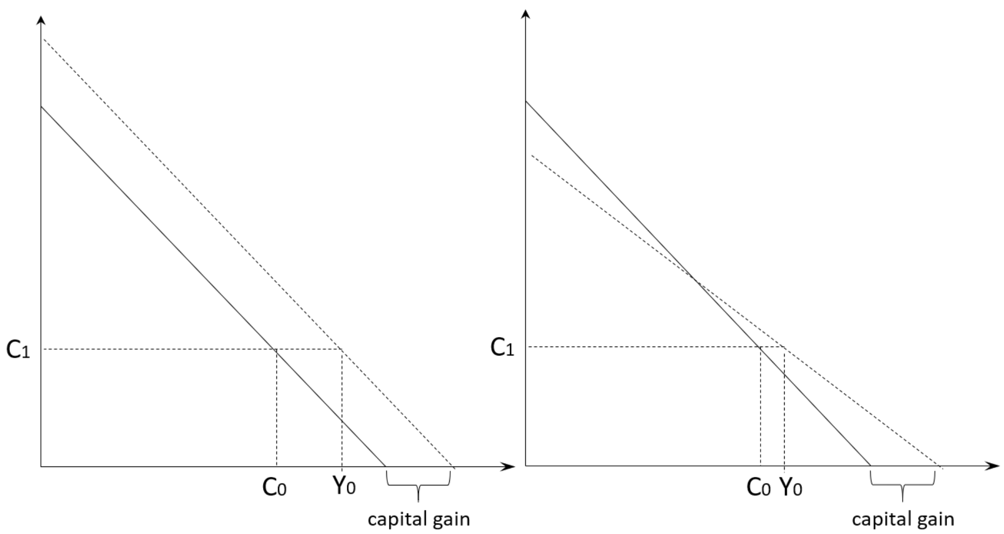
4 Literature Overview

We would like to start our literature discussion by quoting not the earliest but very useful definition of income introduced by Sir John Hicks in the book Value and Capital (1946): a man's income is “the maximum value which he can consume during a week and still expect to be as well off at the end of the week as he was at the beginning”. That is, being “as well off” implies having at the end of the period the same amount of “welfare” as it was at the begging of that period. In practical terms, this means that today's income made up of the consumption that was projected for today plus the present value of any additional current or future consumption that are made possible by today's actions. According to Donald Nichols (1971), this definition is strictly subjective since it makes income dependent upon the “intended future consumption stream”, and therefore institutions holding identical portfolios throughout a period can yet end up with different levels of income. Despite its obvious flaw of subjectivity, Hicksian income definition provides valuable insight: if the fund aims to preserve its real value going forward, its expenses in a given period should be equivalent to the amount it expects to earn during that period. The definition thus emphasizes the importance of linking the endowment spending problem to the endowment income definition and its reasonable long-term expectation.

Such issue is indeed very similar to that of university endowment income as both usually focus on preserving purchasing power and meeting ongoing spending needs. For the university's endowment funds, there exists an extensive discussion in scientific literature, whose major and modern genesis traces back to the earlier 1950s. Broadly speaking, the founding purpose of endowment fund is to support university activities that contribute to a high-quality faculty and facility benefiting both current and future students. However, there are several issues that universities must deal with when spending endowment income with the major concern around the spending policy. Following the ethical principles of prudence and fairness, fiduciaries of endowment funds must not discriminate between generations. This equal treatment requires the endowment manager to form portfolio that would provide appropriate spending today without imperiling the growth of the portfolio going forward. The key issue is to determine the appropriate spending policy and payout rate that would balance this trade-off between current and future spending.

In the 1950s, the common inclination of persons managing university resources was to spend only a part of endowment income as measured by interest and dividends while leaving aside capital gains. This could be explained by an ambiguous nature of capital gains that could increase because of reduction in interest rates (Figure 4.1 – right) or rise in receipts (dividends) (Figure 4.1 – left) making those capital gains not sustainable in long-term.

Figure 4.1. *Different types of capital gains*

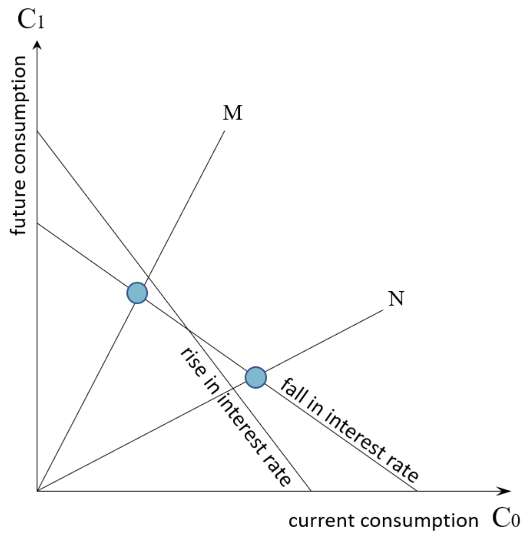


where C_0 *and* C_1 *– current and future consumption,* Y_0 *– income after identical in size capital gain*

Following Nichols, an increase in the prospects of the firm (internal investment interest rate) clearly make the asset holder better off and the present value of the increases in consumption allowed by that change shall be included as a part of permanent income. In contrast, an increase in the market discount rate of future dollars makes one better off or worse off depending on whether one is a buyer or seller of the future dollars whose price falls when the interest rate increases. Therefore, these types of capital gains would affect income differently depending on the asset holder's future consumption plans, and thus cannot be translated into a measure of permanent income until we know the source of the gain and the future consumption plan. It should be clear then that a change in the market value of one's portfolio does not automatically represent an improvement in wellbeing, making capital gains not a proper component of permanent income definition.

This logic is well elaborated by Donald A. Nichols (1974) who supports separate treatment of capital gains based on their source. The idea is that for agents (i.e. funds) who plan to consume more in the future, the fall in interest rates brings negative consequences as future goods become more expensive (Figure 4.2 – plan M). Vice versa, prospects for those who plan to spend more in the short-term horizon improve as their future receipts sacrificed for current consumption increase in value (Figure 4.2 – plan N). As a result, these two forms of capital gains have very different effects on the asset holder's level of welfare and present consumption if utility is to be maximized. At this point, the investor's intertemporal decision problem has been specified without mentioning income definition. However, income concept is still useful in two aspects: *(i)* some budget constraints are defined by income, *(ii)* consumption for the following period is determined given the income level.

Figure 4.2. *Impact on consumption plans from a change in interest rates*



For the endowment fund which consumption can be assumed to grow at a constant, sometimes zero rate, Nichols proposes following income definition that maximizes current level of consumption:

$$Income = R + (G_R - G_C) * V \tag{6}$$

where R – the rate at which dividends and interest are earned on the portfolio, G_R and G_C are the growth of receipts and consumption, and V is the present market value of the portfolio. Clearly, if the positive change in portfolio value V is caused by a change in discount rates and not by increased receipts R or G_R, this should not lead the fund to increase present consumption if it has long-term consumption growth preference, thus income spent today must be limited by $(G_R$-$G_C)^* V$. Effectively ignoring this type of capital gains would tell us how much the fund can optimally expect to spend from the endowment in perpetuity.

Alternatively, Litvack, Milkiel and Quandt (1974) were among the first supporters of employing a broader definition of endowment income, expanding it to capital gains in addition to interest and dividends received. According to the authors, this approach is useful in estimating the fund's overall capacity to buy goods at the present point of time. They further argued that endowment income must be defined in accordance with three criteria: *(i)* investment management must be independent of the spending decisions; *(ii)* a spending rule must protect the real value of the corpus of the endowment fund; and finally, *(iii)* spendable endowment income must be reasonably stable from year to year.

Litvack et al. emphasized that the objective of investment management should be to maximize the total rate of return including capital gains and not only the spendable income which used to be limited to interest and dividend receivables. While the conventional criteria make future spendable income more predictable *(iii)*, they lead to a non-optimal capital allocation inducing investment managers to invest heavily in fixed income securities that can guarantee stable income stream. In fact, a portfolio with large investments in stocks, which pays low dividends but brings large capital gains, creates real value and not just preserves it as it would be thought if capital gains were excluded from income definition. Hence, treating only dividends and interest as spendable income and maximizing them leads to “undesired” protection of the fund's corpus. Thus, an endowment income formula was defined as:

$$V = ((d + c) - g) * M \tag{7}$$

where M is the market value of the portfolio, d is the long-run rate of dividends/interest, c is the long-run rate of capital gains, and g is the desired rate of growth of M.

A slightly different definitions was proposed by James Tobin. Tobin measures permanent (or spendable) income as the sum of dividend and share appreciation multiplied by number of shares (extended for all stocks):

$$Y = (d + (g - i)V) * S \tag{8}$$

where d is the current cash receipts of interest, dividends, and rents per share, g – expected growth per share, i – expected rate of inflation, V – value of a share and S is accordingly the number of shares.

Tobin argues that trustees have zero subjective rate of term preference that effectively eliminates Nichols's statement about ambiguity of utility function. Based on this assumption, he then develops the spending formula permitting a university to consume recurrent capital gains, but to avoid swings of income because of fluctuations in securities prices and changes in discount rates.

Unlike Litvack et al., Tobin introduces a more conservative income definition by estimating a new parameter such as growth rate of earnings from time-series regression of deflated cash yield of U.S. securities per share against time. Hence, he arrives at almost twice less estimates of income increase than the one resulted by assuming pure stock market appreciation (1946-1970). Furthermore, he concludes that a university management is mainly concerned in the income security and not in the stability of its endowment, suggesting that portfolio managers shall be willing to take risk while assuring a growing cash yield.

Since then, a broader outlook on endowment income and spending policy has emerged. For example, Merton (1991) suggests including both tangible and intangible sources of income such as tuitions, gifts, grants, etc., that must be considered to achieve an optimal asset allocation of endowment portfolio, which would largely deviate from mean-variance efficiency. According to Merton, the mean-variance efficient portfolio would then aim not only to achieve less risk and higher return, but also account for the need to hedge future costs against shift in income sources resulting from the correlation between gift giving and risky asset returns (i.e. gift giving increases during market growth, which is typically associated with higher returns in stock markets).

Another interesting approach to optimal portfolio construction was proposed by Philip H. Dybvig in the late 1990s. Dybvig suggests using dynamic link between asset allocation and payout rule by preserving spending power in down markets but participating largely in up markets. This is achieved by partitioning the endowment portfolio into a risky part and a “protected” part. The latter part is effectively immunized by risk-free investments and imposed limitations regarding investments in risky securities during market downturns. This approach resembles core-satellite investing, where protected part (committed account) ensures predicted expenditures/commitments, while risky part (cushion account) participates in market growth. Following this strategy, if portfolio value increases significantly, it stimulates increase in spending rate; however, when market underperforms, investments from cushion account are transferred into committed account to preserve spending capabilities. According to Dybvig, such strategy leads to improved performance during market extremes but underperforms when portfolio is affected by volatility from alternating market ups and downs.

Spatt (1999) explored the various implications of the traditional theories for university endowment, emphasizing their limitations and potential problems arising in the actual endowment management practices. He suggests that a widespread moving-average spending rule, which is based upon the average of past fund values, does not always efficiently smooth spending because of its suboptimality in an expected-utility formulation. As understood by the author, the optimal policy of a risk-averse entity should indeed embody smoothing of spending, but the optimal rule should not be backward-looking in an expected-utility framework. Instead, the optimal payout rule should reflect "smoothing" by incorporating gradual spending of gifts and returns over the future ("smoothing" in a forward-looking manner). Unless the fund's preferences embody large adjustment costs to changing spending, the current market value of the endowment should drive the spending decision. Similarly, Spatt argues that the fund's asset allocation should be based on the present market value of the fund rather than past values, suggesting the benefit of using stable asset allocation policies over derivative-based policies, where the asset allocation is determined by prior values of the endowment. The derivative-based approach typically arises in two cases: *(i)* when the endowment manager attempts to reduce exposure to risk after poor returns to limit downside potential; and *(ii)* when the endowment manager wants to replace upside returns for downside protection ("costless collar"). The exposure variation imposes significant risk on the fund, since it is not highly efficient relative to a stable asset allocation policy and does not provide a proper risk premium because of the nature of an equilibrium pricing of risk that is not positively supplied in the economy.

Most equilibrium models state that investors generally benefit from holding portfolios that provide counter-cyclical payouts. Since the marginal utility of consumption is high during market downturns, investors are more likely to depend on additional income at that time. For the same reason, investors are less likely to depend on additional income during economic booms. Endowments and sovereign wealth funds are not exceptions to the rule. Dietz, McKleever, Steele, and Steuerle (2015) elaborated more on this topic within the framework of granting foundations that serve as a significant source of capital for the charitable sector in the United States. The authors suggest that a commonly used fixed percent payout rule, by its nature, makes a fund's spending procyclical. That is, as the economy, particularly the stock market in which significant portion of endowment portfolio is typically invested, falls and rises, fund's payout also falls and rises with it accordingly. Thus, when market downturns leave the beneficiaries most in need of funding, funds pay out the least.

The issue is getting more complicated when perpetual lifespan of endowment funds is considered. Unlike individual investors, foundations must operate to benefit equally both current and future generations. By paying out more during economic downturns, a foundation might lose a significant share of its market value and thus jeopardize its ability to benefit future generations. Dietz et al. proposed legal changes, such as the excise tax and carry-back and carry-forward rules, to encourage or at least not to decrease the dollar value of grantmaking during economic downturns. They further suggested to conduct a more in-depth research on portfolio management techniques that could minimize risk to both grantors and grantees.

Another notable study that supported increased spending was done by Altshuler (2000). He made a strong statement about university endowment funds that, as he says, are “too stingy” and are not spending enough on important development of faculty and academic programs. Hansmann (1990) supported this argument by citing the evidence of significant stock price appreciation during the 1990s and questioned the low spending rates offered to academic programs at that period. He, further, postulated that endowment managers are giving more attention to portfolio management and growth of the endowment fund at the expense of prudent spending rate policies. Although both authors were studying the university endowment funds, the same critique might be addressed towards sovereign wealth funds whose goal is to meet public expenditures.

The impact of economic downturn on performance of endowment funds was also discussed by Hannon & Hammond (2003). In contrast to Dietz et al, the authors suggest endowment funds to cut payout rates and spending during market falls arguing that keeping payout rates on the same level or rising them would significantly impair endowment value; and if this happens, as concluded by the authors, the recovery of initial fund's market value might take decades, if it can be done at all.

Another study on endowment management that is worth mentioning was done by Richard Grinold, David Hopkins and William Massy, and is called "A model for long-range university budget planning under uncertainty" (1978). The authors developed a linear control model of a university budget to improve strategies for dealing with various exogenous factors, mainly related to inflation, endowment returns, and fund-raising. The model is built to balance budget growth by closely following prescribed limits for several financial ratios, including the ratio of the budget to the endowment. By simulating market behavior, they estimated the sensitivity of the model to the changes in the ratios and the impact of incorrect assumptions on the fund's value. This work serves as one of the first examples of the dynamic budget representation.

In response to a call for more research using advanced analytical tools, Milvesky and Robinson (2005) presented a forward-looking approach for analyzing payout rates based on stochastic present value measure instead of using "opaque" Monte Carlo simulation. By investigating interaction between spending rate and asset allocation decisions, the authors concluded that payout rates must be lower than those many endowments use in practice. Following their approach, the probability of fund exhaustion significantly increases when returns are volatile, and payouts are fixed or increase at a constant rate. Depending on the payout rate and asset allocation (i.e., 100% equity or 50% equity and 50% bonds), Milevsky and Robinson estimated the significant likelihood of endowment's failure ranging from 45% to 84%. For example, for an all-equity portfolio with mean return of 7 percent and volatility of 20 percent, the fund would stay sustainable by spending a maximum of 3 percent of initial capital.

More recent example refers to Marshall Blume (2010) who discussed applicability of different payout rules such as: *(i)* flexible rule, based on Fund's current value, *(ii)* moving average rule, based on average of previous market values of endowment, and *(iii)* Ratchet rule, which implies strictly non-decreasing absolute payout each year. The latter Ratchet rule naturally looks riskier as payout is not adjusted to the Fund's performance, while Flexible rule (to which most of private foundations must adhere) brings undesired volatility in expenditures as it fully coincides with the Fund's annual performance. On the contrary, average rule gives the possibility to participate in both downturns and upturns but with a predefined lag and that is indeed the rule which most university endowments follow. Author concludes that the endowment must determine its spending policy together and investment strategy simultaneously. For players with long-term horizon and thus riskier portfolio, usual concern is larger short-term volatility. Therefore, the Fund may intentionally choose underperforming long-term strategy to lower fluctuations in the Fund's value and in subsequent payouts.

In a non-perfect capital market, earnings are distorted by tax considerations making the question of time preference more ambiguous. The latter occurs because there is a constant inclination to spend more today as future is uncertain and predominantly mortal. For example, if some citizens leave a country or they choose not to leave any descendants, it is not clear then how to account for utility function. There may be a reason to argue that probability of requiring income from endowment will likely decline over time, thus justifying higher spending today. To address this issue, a more straightforward approach dealing with market returns and considering capital gains was proposed by the American Economic Association (AEA). It states that if the capital gains are not planned to be spend permanently at the equal rate, some of them can be spent today as comes a priori and formally by, for instance, F. Modigliani's life-cycle hypothesis or M. Friedman's consumption/permanent income (one chooses his spending in line with his long-term expected average income) function.

Other authors emphasize the importance of financial management systems and spending controls in managing endowment funds. Based on the analysis of sovereign funds in the Pacific Island countries, Le Borgne and Medas (2008) concluded that the poor performance of the government funds can be caused by the weakness of public management systems and the lack of proper spending controls. For example, in some instances, the firm operational rules hampered the fund's ability to reduce revenue fluctuations. Another example is when management's ambitions of increasing financial returns lead to risky investments, mismanagement, and significant losses in value.

As most oil exporters, Norway does not consider below-ground assets when allocating its sovereign wealth fund portfolio and ignores above-ground assets when extracting oil. Ton van den Bremer, Frederick van der Ploeg, and Samuel Wills (2014) have presented a unified framework for considering both by integrating the theories of portfolio allocation, precautionary saving, and optimal oil extraction under oil- and asset-price volatility. In their paper, the authors argued as follows: *(i)* commodity exporting countries should change the allocation of their SWF by leveraging all risky assets and hedging subsoil oil risk. These effects are proportional to the ratio of oil and fund wealth, so they need to be unwound as resource reserves are depleted; *(ii)* consumption should be a constant share of total oil and fund wealth; *(iii)* if oil wealth cannot be adequately hedged, then less should be consumed initially in the interests of precautionary savings.

These arguments are in sharp contrast to what sovereign wealth funds do in practice. For example, the GPFG invests in the market portfolio without considering oil price risk. The fund used to spend up to 4 percent of its value yearly, building up a precautionary buffer but not really counting the decreasing oil reserves. Bremer et al. state that if Norway implement this theory properly then it can improve its welfare by the amount equivalent to a 15% permanent increase in the fund's dividend. However, they also point out that this would be difficult to implement in reality because of short-sale constraints, transaction costs and unstable relationships between assets. That's why they proposed to take the extraction path as given, invest only in the market portfolio, but alter the equity/bond mix and change the spending rule. This approach would then be more transparent and less costly, not require shorting, and easier to implement. Following this approach, the equity mix in the portfolio increases from 45 percent to 60 percent as oil reserves decrease, while consumption falls to below 3 percent of funds value. In total, this approach brings improvement, equivalent to 58 percent of the first-policy welfare.

Gondesi and Bandi (2018) considered a unified treatment of spending and asset allocation decisions arguing that their separation leads to sub-optimality in respect to the objectives of an endowment. Based on the broad discussion about performance of existing payout rules used by endowment managers worldwide, Gondesi and Bandi assumed that application of an approximate model is preferred over deterministic empirical spending rules. They further proposed to create a model as a Stochastic Dynamic Program, arguing that existing academic literature on endowment still lacks research on the question of determining spending rates using advanced analytical techniques. Since solving stochastic dynamic programs is virtually intractable, the authors used Discretization and Value Fraction Approximation to develop new methodologies that are tractable in both cases of low and high dimensionality (Robust

Optimization). In particular, four types of uncertainty set with distinct levels of risk aversion and other priorities were constructed in a way that introduces them as tractable linear programming problems. The new methodology was compared against MIT's spending policy and Tobin's rule based on different desired features of a spending policy, such as market value of the endowment after a specified period and the smoothness in the spending amounts from year to year. In the end, Gondesi and Bandi concluded that their approach outperforms in many features the Tobin's rule, and introduces additional desirable properties such as higher flexibility and control over the behavior of the spending policy.

Two master theses (2005, 2012) in BI Norwegian Business School were straightforwardly devoted to the problem of GPFG's payout rule and both have found that % rule is unsustainable in the long run. While not specifying exact payout rate desired, simulations implying average rule (based on funds previous market values), GDP rule (as a % of GDP rather than Fund value), and Ratchet rule (implying never decreasing spending) showed long-term (50 years) underperformance of fixed 4% withdrawals in terms of absolute payout amount compared to somewhat lower expense rate.

Over the last fifty years, many kinds of the payout practices have been put forward and studied to address different aspects of the endowment spending problem. Yet, the scientific literature still lacks a coherent modeling framework on which to base the discussion. A large share of existing studies on endowment and sovereign wealth funds keep arguing that current payout rates should be reduced if the fund embodies to preserve its value going forward. Alternatively, some finance advisors argue that endowments are “too stingy” and are not spending enough; endowment funds keep accumulating financial wealth by not shifting enough funding to meet current public needs, such as development of intellectual capital, infrastructure, etc. Furthermore, a few endowment managers put a strong statement questioning the policy of holding current spending below the expected rate of return, suggesting that such policy shifts all the risk involved in future asset returns onto present shoulders, and none of it onto future generations. The purpose of this paper is thus to apply both the existing scientific literature and our simulation model to investigate the sustainability of Norway's payout rule.

5 Methodology

To investigate our research question about the sustainability of the payout rule, we propose to test the following null hypothesis:

$$H_o : the\ payout\ rule\ is\ sustainable\ in\ the\ long\ run$$

Three criteria were identified in order to evaluate the sustainability of the payout rule. For each criterion, we have further proposed several measures to determine statistically how well the payout rule satisfies each of them. Since the results from testing the current Fund's payout rule might not be sufficient to make reliable conclusions regarding our hypothesis, we will therefore test several payout rules with distinctive properties. These benchmarks will be then used as a point of comparison, which will help us deduce if the payout rule is sustainable in the long run or not. In order to answer the question of how much can the Norwegian government safely withdraw from its SWF without imperiling its existence, we will implement a sensitivity test. In particular, a sensitivity test will show us whether the government shall reduce the average payout rule and how substantially it should be lower than the average expected return on the endowment. In our simulation we will assume that **no more inflows are transferred** into the Fund.

5.1 *Payout rules criteria*

Traditionally, the primary goal of endowment managers has been to maintain endowments in perpetuity to ensure a consistent and reliable level of investment income for generations to come. It has also been the view that endowments should be used to support the Fund's mission, which translates into spending as much as possible while maintaining the former objective. To be precise, an acceptable spending policy should accomplish the following:

(i) The endowment spending policy should protect the real purchasing power of the endowment over time

If an endowment spending rule is built such that the real value of the Fund is preserved, both present and future generations will equally benefit from the endowment financing.

(ii) The policy should maximize average real payouts in the long-term

As a perpetual institution, GPFG can define its preferences in terms of a long-run criterion function such as maximizing the expected utility from its operations over time. According to Spatt (1999), the utility of the Fund can be specified as being over its overall intertemporal stream of (real) expenditures. An endowment should therefore be managed such that it does not only maintains the real value, but also maximizes long-term spending. If not, one could end up with a payout rule that preserves the Fund's value and low volatility, but produces modest annual payouts. Having the level of spending low enough that most of the time earnings are more than sufficient to cover it, means that in most years the excess return can be added to the endowment – which may lead to an unfair distribution of the resources, wherein the current generation bears the risk of future returns (Mehrling & al, 1999).

Institutions willingly increase their spending as their endowments rise in value. Yet, most institutions often find it extremely painful to reduce spending as their endowments fall in value (Blume, 2010). Since the Norwegian government relies on its endowment income to cover an ongoing stream of public expenditures, stable payouts are highly desirable. As argued by Barro (1979) and others, the stream of government services ought to be smooth, and this smoothness should work backward as well as forward. That is, policy makers should not only plan for smoothness in future services and tax rates, they should also avoid sudden changes from past patterns in response to unexpected shocks. A smooth payout will ensure predictable budgeting for the Norwegian government that in turn may lead to stability for the economy as a whole. When considered in the context of growing pension, health service and elderly care expenditures, this criterion is becoming increasingly important. Moreover, Dietz et al. (2015) and Rooney et al. (2014) add another important comment by stressing the value of a counter-cyclical, supplemental payout by foundations during economic downturns, when the dollars granted are the most needed by society. To address these issues, we thus add an additional payout criterion:

(iii) The spending rate should produce stable and slightly counter-cyclical payouts over time. (i.e., higher payouts in bad economic times than in good times)

These criteria will to some extent conflict, especially the first and second criteria. Asset returns act like random variables, and that variation presents a problem for the concept of intergenerational equity (Mehrling, 1999). If the government aims to provide generations a steady amount of spending, then it cannot guarantee a fixed corpus. And the opposite is also true. It thus seems that one must choose between the interests of the beneficiaries (fixed spending) and the interests of the trustees (fixed endowment). We assume that no one payout rule will effectively meet all three criteria, chosen as the basis for determining whether the Payout rule is sustainable, or not. Nonetheless, it is desirable that the rule provides a healthy balance between them.

5.2 *Evaluation of criteria*

(i) One of the ways to verify the first criterion (Fund reduction) is to use the spending policy for a given number of years and compare the real purchasing power of the endowment at the end of the testing period with the initial Fund value. As such, we will explore the real end values of the portfolio to discover in how many of the simulations these values are below the initial Fund value

(Bandi & Gondesi, 2018). This will reveal whether the Fund has been able to maintain its value over the forecasted period. However, even if the end values are lower than the initial value, there is still a probability that the Fund will overcome losses and maintain its value over a longer time period. We will therefore explore in how many of the simulations the real end value of the portfolio drops below 25% and 50% of the initial capital (9) and of the historical Fund's maximum level (10). If the Fund value (F) drops below these levels, it would need to earn 33.33% and 100% respectively in order to recover back to its initial value. It seems exceptionally difficult even over a longer time horizon to earn 100% on the remaining capital, this is why a reduction of 50% and more in the endowment value will be deemed as a failure.

$$Prob\,(F_T < 0.75 * F_0\ )\ |\ \ Prob(F_T < 0.5 * F_0) \tag{9}$$

where $F_0 = 8256$ NOK – Fund's value as of December 31, 2018

$$Prob\,(F_T < 0.75 * F_{Max}\ )\ |\ \ Prob(F_T < 0.5 * F_{Max}) \tag{10}$$

where $F_{Max} = \max_{t\epsilon(0,T)} F_t$

Additionally, Fund's value distribution (10%, 25%, 50%, 75%, 90% percentiles) is presented in Appendix F.

(ii) The second criterion (Payout reduction) is evaluated by calculating the mean of the annual real payouts over the forecasted period. This value will tell us of how much the payout rule allows to be spent on average. As the Norwegian government has spent annually on average 229.3 [12] billion over the last three years, we assume that this spending level will be maintained and therefore establish the first-year average payout to be within 10% of the last three-year average (National budget 2019, p.7). Since the average annual growth in the market value of the Fund over the last three years (i.e., 2016 –

[12] $(231.1 + 231.2 + 225.6)/3 = 229.3$

2018) has been approximately 3.6% (NBIM), we find it reasonable to set the average payout over the forecasted period to be around 3.6% above the average of the last three years. To put it simply, we want to see an average annual withdrawal (W) of at least 237 billion NOK over the forecasted period (11).

$$Prob(\left(\frac{\sum_1^T W_t}{T}\right) < 237bn\ NOK) \tag{11}$$

Additionally, withdrawals value distribution (10%, 25%, 50%, 75%, 90% percentiles) is presented in Appendix F.

(iii) To evaluate the third criterion (Payout instability), we assess the volatility of the expected payouts and the volatility of the yearly changes in expected payouts. Specifically, we would compute the cross-sectional standard deviation of withdrawals (across simulations) for each 10-year period (12); and simultaneously we would also keep track of volatility of an annual percentage change in withdrawals (13). Every volatility would be presented in a percentage form. As the GPFG targets stable long-term withdrawal policy, excessive volatility in withdrawal amounts, especially negative one, is highly undesirable. To quantify, the "excessive" volatility is defined as the one over 20%, as such instability could significantly worsen consumption patterns.

$$\sigma\left(W_{t=10,t=20,\ t=30}\right) \geq 20\% \tag{12}$$

$$\sigma(\Delta W_{t,t+1}) \geq 20\% \tag{13}$$

Additionally, we present distribution (10%, 25%, 50%, 75%, 90% percentiles) of such volatilities in Appendix F.

5.3 *Payout rules*

We shall first explore the Fund's current payout rule, which is using a prespecified spending rate (initially estimated as 4%, then lowered to 3%) corresponding to the expected real financial return as an average target based on a year-to-year need. However, the results from testing the Fund's current payout rule alone might not be sufficient to make reliable conclusions about our hypothesis. We will therefore examine three alternative payout rules with distinctive properties suggested by the literature on endowment spending. Our objective is to investigate the impact of the different rules on the sustainability and purchasing power of the Fund.

5.3.1 *Fixed rule*

Since Norway's current 3-percent spending rule is not intended as a cap, but as an average target – Norwegian government can go below or above that figure in given years – we cannot provide any exact estimates for future yearly withdrawals. Thus, we use a proxy equal to a fixed yearly withdrawal rate of 3% which is the government's long-term expected spending. The spending will therefore immediately increase or decrease as the value of an endowment changes and will look as follows:

$$Spending_N = Spending\ rate(\cong 3\%)\ \times Asset\ mkt\ value_{N-1}$$

We assume that the flexible 3-percent rule will result in a moderate probability of maintaining real Fund value over the forecasted horizon (First criterion) as the payout is highly responsive to the Fund's value changes, high average payout (Second criterion), and high payout volatility (Third criterion).

5.3.2 *Average Rule*

The third rule to examine is an Average Rule, where spending from endowment is based on a pre-defined percent of a base determined by a moving average of past (market) endowment values (Blume, 2010). The average rule allows for both upwards and downwards adjustment but with a lag. In other words, if the endowment declines by for instance 30 percent and remains the same for the next two years, the Fund using a typical three-year average will see its spending levels drop 10 percent per year for each of the following three years for a total drop of 30 percent – not 30 percent in one year. This is how the spending formula based on a K-year period looks like:

$$Spending_N = Spending\, rate\, (\cong 3\%) \times \frac{1}{K}(Mkt\ value_{N-1} + \cdots + Mkt\ value_{N-K})$$

In analyzing the average rule, we focus on two versions of the rule to calculate the base upon which the spending level is derived – a three-year average *(K=3)* and a five-year average *(K=5)* of past endowment values. Endowment spending will therefore always depend on the Funds average market value over the last three or five years, rather than only on the Fund's current value. We set the spending rate equal to 3 percent of the base, which is the current government's long-term expected spending rate, for both scenarios. To find the initial base value for a three-year average, we use three prior year-end (lagged) market values. Thereby, the first-year base is 8256 billion NOK. To calculate the second- and third-year bases, we replace the last lagged variables with one and two simulated values respectively. The same procedure is used to find the initial base for a five-year average rule.

We assume that this type of payout rule will result in a smoother and more uniform spending path compared to the Flexible and Ratchet Rules. This is mainly because high fluctuations in the endowment value would not immediately result in high decreases or increases in withdrawals from the Fund. However, the moving average rule does not guarantee improvement in Fund's performance, in particular, during financial crises (Bandi & Gondesi, 2018). With the burst of the tech bubble on Wall Street in 2001, most institutions that relied on a moving-average rule, owing to its simplicity and booming financial conditions in the 1990s, experienced substantial losses in average endowment value. In contrast, average spending rates during this period did not show much variation, which consequently led to a faster deterioration of the endowments. Hence, we would expect moderate probability of Fund value preservation, moderate payout, and their low volatility.

5.3.3 ***Ratchet Rule***

We will also explore the other payout rule that is extreme in that it never reduces spending no matter how poorly the endowment performs. This payout rule will be termed the Ratchet Rule, similar to the one proposed by Blume (2010), and it shall capture the tendency for a Fund to increase spending as the endowment value increases while maintaining it when the endowment drops. It follows therefore that the government will never have to cut spending and ensures greater predictability in terms of future budgets.

$$Spending_N = \max_{N\epsilon(0,T)} (\ Spending\, rate\, (\cong 3\%) \times Asset\ mkt\ value_{N-1}, \quad Spending_{N-1})$$

We will pick a 3-percent initial spending level of the current value of the endowment at the beginning of the first year. The spending level in each of the subsequent years will be the maximum of: *(i)* the nominal value of the spending level from the prior year, or *(ii)* a spending level determined by the product of the initial percent and the current value the endowment at the beginning of the year. Consequently, the probability that the spending pattern of an institution could conform to this rule over an extended number of years is of interest. We anticipate that this rule would result in high probability of Fund failure, high average payout and moderate volatility of payouts.

5.3.4 ***GDP Rule***

The payout rule specified as a share of GDP is the common practice of targeting a sustainable nonoil budget deficit among sovereign wealth Funds. The implication of this rule is that spending is tied to GDP and not the value of the

Fund. Endowment spending will therefore increase in line with the rest of the economy and not at the expense of it. Norway's current fiscal rule constrains the non-oil deficit as a share of GPFG assets, but not relative to mainland GDP. As a result of this policy, large increase in GPFG assets during high petroleum industry growth led to a gradual increase in the non-oil deficit as a share of the mainland GDP and added further pressure on the economy. Using the GDP payout rule will help the government hold endowment spending at moderate levels in periods with strong returns. However, in periods of poor returns, the non-oil deficit will still be kept as a fixed share of mainland GDP, which may lead to substantial reduction in the endowment.

$$Spending_N = Spending\ rate(\cong 7\%)\ \times GDP_N$$

In the years preceding the financial crisis the non-oil budget deficit was from 3% to 3.5% of the mainland economy, it then increased to almost 5 percent during the financial crisis. Over the last few years, the non-oil budget deficit has reached approximately 7.5%. We will thus analyze a rule that spends a fixed proportion of 7% of the GDP level in any given year to account for current spending levels. Spending rule that is below 7% will not meet our requirement and hence will be ignored. Here, the expectations are high chance of the Fund's decline, high average payout, and its moderate to low volatility.

6 Data

To build and evaluate forecasts of the future performance of the GPFG, we have used observed historical data that largely reflects the current distribution of the Fund's portfolio. The mandate introduced in 2017, where the equity and fixed income portfolio allocation accounts for 70 and 30 percent of the strategic benchmark index respectively, serve as the proxy in our simulation (Redjeringen). Real Estate investments were ignored because of their marginal size and lack of predictability. The regional distribution across countries and geographical regions is based on a principle of market weighting for equities and corporate bonds, while for government bonds it is based on the relative size of countries' economies, as measured by the Gross domestic product (GDP). These weights are assumed to remain stable for the whole forecasted period.

6.1 *Data Source*

The data for equity, fixed income, and currency exchange rates were extracted from DataStream Advance 5.1 provided by Thomson Reuters. The equity portfolio was constructed using the MSCI World Index (launched on Dec 31, 1969) for developed markets and MSCI Emerging Markets Index (launched on Jun 30, 1988) for global emerging markets. We then used long-term government bond yields to calculate returns for the government part in the fixed income portfolio and Bloomberg Barclays Global-Aggregate Index for the corporate portion of the bond portfolio. In total, we have collected data on 52 countries in the equity portfolio and 48 countries in the fixed income portfolio. An extract of these data can be seen in Table 1.

All equity indices were downloaded as total return indices in the United States Dollar (USD) to measure performance more accurately by assuming that all

Table 1. *Equity and Fixed Income Codes for the Fund's largest holdings by country, Dec 31, 2018*

Country	Equity codes	Fixed Income codes	Fixed Income maturity
United States	MSUSAM$(MSRI)	USOIR080R	10
Japan	MSJPAN$(MSRI)	TRJP10T	10
United Kingdom	MSUTDK$(MSRI)	UKOIR080R	10
Germany	MSGERM$(MSRI)	BDGBOND	10
France	MSFRNC$(MSRI)	FRGBOND	7
Switzerland	MSSWIT$(MSRI)	SWOIR080R	10
Canada	MSCNDA$(MSRI)	CHOIR080R	10
China	MSCHIN$(MSRI)	TRCH10T	10
Australia	MSAUST$(MSRI)	AUGBOND	10
Spain	MSSPAN$(MSRI)	ESOIR080R	10

cash distributions, such as dividends, are reinvested over time, in addition to tracking the price movements of the securities. Long-term government bond yields were downloaded in local currencies and then converted to USD using the MSCI exchange rates between the local currencies in our fixed income portfolio and USD. In addition, as the Euro (EUR) currency was introduced in 1999, we also downloaded the MSCI EUR/USD exchange rate from its inception. Finally, to convert all returns into Norwegian krone (NOK), we used the MSCI NOK/USD exchange rate. All data were obtained with monthly frequency using average conversion method (data on the mid-day of the month) and spanned back to 1970. By using the same source throughout the whole dataset, consistency is ensured.

The index for historical inflation in Norway has been downloaded from Statistics Norway's website `(ssb.no)`. We used the consumer price index (CPI), not seasonally adjusted, starting from 01.01.1970. Additionally, we downloaded the annual Norwegian nominal GDP and GDP deflator since 1970 from Statistics of Norway website.

Table 2. *Summary Statistics for the 48-year observed period, 1970 – 2018*

1970-2018	geometric mean	arithmetic mean	standard deviation
GDP growth	2,86%	2,88%	1,80%
GDP deflator	4,99%	5,09%	4,80%
CPI	1,66%	1,66%	1,22%

1970-2000	geometric mean	arithmetic mean	standard deviation
GDP growth	3,60%	3,61%	1,68%
GDP deflator	6,16%	6,24%	4,27%
CPI	2,12%	2,13%	1,25%

2001-2018	geometric mean	arithmetic mean	standard deviation
GDP growth	1,61%	1,62%	1,22%
GDP deflator	3,02%	3,10%	4,22%
CPI	0,86%	0,86%	0,64%

6.2 *Data Treatment*

The obtained equity and corporate bond return indices were quoted in prices that needed to be converted to returns. This has been done by assuming continuously compounded monthly returns by taking the natural logarithm of the gross monthly returns as follows:

$$R_t = \ln\left(\frac{I_t}{I_{t-1}}\right)$$

I_t and I_{t-1} represent an index value at time t and *t-1* respectively and R_t is thus a monthly return. Similarly, monthly inflation has also been computed from the consumer price index (CPI) using the above formula. To estimate returns for the government part of the fixed income portfolio, long-term government yields were obtained and transformed into returns using Morningstar Methodology Paper (2008) on Return Calculation of U.S. Treasury Constant Maturity Indices. Since the yields are interpolated from the yield curve, insufficient information exists to calculate returns precisely, but approximations can be estimated by making several important assumptions. Following are the assumptions made in the return calculation of the long-term government bond yield indices:

(i) Each index consists of a single coupon bond.

(ii) In the middle of each month a bond is purchased at the prior monthly period-end price, and daily returns in the month reflect the change in daily valuation of this bond.

(iii) Coupon is paid on the mid-month date of every six months from the purchase day.

(iv) Each bond is trading at par upon purchase.

(v) The yield curve is flat at the desired time to maturity.

The first step in calculating the bond returns involves estimating the coupon bond prices, which are driven by the yield, the time to maturity, the coupon payments, and the face value. As the coupon rates of these indices are typically not provided by banks, we have assumed that the coupon rate is the same as the yield by accepting that the bond is trading at par. A bond that is trading at par is known to be priced at 100, and its yield must be equal to the coupon rate. We have assumed annual coupon payments for most countries in our portfolio, except for Canada, United Kingdom, and the United States, where semiannual coupon payments are used.

Furthermore, the government bond indices' yields at the end of the holding period are not available. In other words, at the end of a one-month holding period, a bond that had, for instance, one year to maturity at the start of the holding period currently has 11-month left to maturity, and banks do not typically provide the yield of a 11-month bond. By assuming the yield curve being flat in this period, the yield of a newly issued one-year bond can be used as the yield of the old bond that has 11 months left to maturity.

where: *P(t, y, m)* = price of the bond with maturity date *m*, yield *y*, at time

$$P(t,y,m) = \left[\frac{100}{(1+y)^{N_m - 1 + \frac{D_{t,m}}{S_m}}}\right] + \left\{100\frac{y_{p,m}}{y}(1+y)^{1-\frac{D_{t,m}}{S_m}}\left[1-(1+y)^{-N_m}\right]\right\}$$

t

y = yield, also known as interest rate (decimal form)

N_m = maturity of the bond (number of years)

$D_{t,\ m}$ = number of days between time ?t? and the next coupon date of the bond

S_m = number of days in the coupon period in which time "t" falls (first coupon period)

$Y_{p,m}$ = coupon rate (equal to yield on purchase day p)

c_m = day of first coupon payment

With adjustment for semi-annual coupon payments, the bond pricing formula is:

$$P(t,y,m) = \left[\frac{100}{(1+\frac{y}{2})^{2N_m-1+\frac{D_{t,m}}{S_m}}}\right] + \left\{100\,\frac{y_{p,m}}{y}(1+\frac{y}{2})^{1-\frac{D_{t,m}}{S_m}}\left[1-(1+\frac{y}{2})^{-2N_m}\right]\right\}$$

We then assumed that a government bond is purchased on the mid-date of each month starting from time-zero (i.e., Dec 15, 1969), held for one-month period and then sold. This process is repeated for every month in the dataset. We thus computed the total holding returns using the formula below:

where: $P(t_1,\ y_{t1},\ m)$ = price of the bond with maturity date m, yield y_{t1}, at

$$TR_{t_1t_2} = \frac{P(t_2, y_{t_2,m}, m)}{P(t_1, y_{t_1,m}, m)} - 1$$

time t_1 $P(t_2,\ y_{t2},\ m)$ = price of the bond with maturity date m, yield y_{t1}, at time t_1.

The maturity date, denoted as m, reflects the maturity of the index at purchase, while y_{t2} and y_{t1} reflect bond yields at periods t_2 and t_1 respectively.

Thereafter we initiated a total return index with value 100 and multiplied it by the exponential of next month's return. Finally, the total return index was converted from local currency to USD and then to NOK (Table 3). With establishment of the euro currency, an additional step was necessary to calculate the total return index in NOK for those countries that officially adopted the Euro. In particular, the total return index in the preceding local currency had to be replaced by the Euro at a fixed parity rate and only then be converted to USD and NOK.

Table 3. *Government Bond return calculation*

Switzerland												
Date	Yield (%)	Coupon rate (%)	Maturity	Purchase	Resale	Return	Total return CHF	Exchange rate CHF/USD	Total return USD	Exchange rate NOK/CHF	Total return NOK	Total return NOK (%)
15.12.1999	5,3%	5,3%	10	100			100	4,32	23,14	7,14	165,27	
15.01.2000	5,3%	5,3%	10	100	105,5	0,52%	100,5	4,32	23,26	7,14	166,13	0,52%
15.02.2000	5,6%	5,6%	10	100	98,8	-1,20%	99,3	4,32	22,98	7,14	164,13	-1,20%
15.03.2000	5,7%	5,7%	10	100	99,6	-0,40%	98,9	4,32	22,89	7,14	163,47	-0,40%
15.04.2000	5,9%	5,9%	10	100	98,9	-1,15%	97,8	4,32	22,62	7,14	161,59	-1,15%

The table above presents the example of return estimations based on Switzerland 10-Year Government Bond Yield. Monthly yields are first computed into monthly returns. A local currency index is initiated at 100 and multiplied by the monthly return. This index is converted into US dollars and then into NOK. Finally, the Norwegian monthly return is computed.

6.2.1 *Customizing weights*

At the end of 2018, the Fund spanned 73 countries and 50 currencies. In order to improve accuracy of our model, we have built a portfolio that largely reflects the current geographic and regional distribution of the Fund's assets. Our replica portfolio thus consists of 59 countries including the most heavily weighted countries within the GPFG's portfolio. Due to the absence of several countries in the replicated portfolio, the new customized total portfolio weights for each country and region were estimated (Appendix C). For the equity part, we first found the actual amount invested within each country and each region. Actual country weights were then estimated by dividing the actual amount invested in each country by the total equity market value. The regional weights in the strategic benchmark portfolio were then divided by the regional weights in the replicated portfolio to obtain a re-weighting coefficient. Finally, new weights were found by multiplying this coefficient by actual weights. Similarly, we estimated the new customized weights for the fixed income investments by sector, which included government and corporate bonds (Table 4). In total, our data covered 99.6% of the total Equity portfolio and 97.9% of the Fixed income portfolio.

Table 4. *Norwegian GPFG constructed portfolio*

	Equity			Fixed income		
Country	**Investment (MM NOK)**	**Actual share**	**Customized share**	**Investment (MM NOK)**	**Actual share**	**Customized share**
Australia	116,94	2,14%	2,15%	54,72	2,16%	2,23%
New Zealand	6,76	0,12%	0,12%	6,35	0,25%	0,26%
Brazil	53,45	0,98%	0,98%	23,46	0,93%	0,95%
Chile	7,42	0,14%	0,14%	1,98	0,08%	0,08%
Mexico	17,74	0,32%	0,32%	46,18	1,82%	1,88%
Colombia	3,93	0,07%	0,07%	11,00	0,43%	0,45%
Peru	1,89	0,03%	0,03%			
USA	2124,61	38,79%	38,79%	651,99	25,74%	26,51%
Canada	118,54	2,16%	2,16%	97,44	3,85%	3,96%
Austria	12,39	0,23%	0,23%	15,55	0,61%	0,63%
Belgium	34,99	0,64%	0,64%	19,97	0,79%	0,81%
Croatia				0,20	0,01%	0,01%
Cyprus				0,49	0,02%	0,02%
Slovakia				3,92	0,15%	0,16%
Slovenia				4,76	0,19%	0,19%
Czechia	0,32	0,01%	0,01%	0,33	0,01%	0,01%
Denmark	51,41	0,94%	0,94%	11,26	0,44%	0,46%
Finland	41,46	0,76%	0,76%	14,51	0,57%	0,59%
France	278,33	5,08%	5,07%	64,97	2,56%	2,64%
Germany	267,99	4,89%	4,89%	171,68	6,78%	6,98%
Greece	3,26	0,06%	0,06%			
Hungary	0,64	0,01%	0,01%	0,55	0,02%	0,02%
Iceland				0,98	0,04%	0,04%
Ireland	6,33	0,12%	0,12%	7,54	0,30%	0,31%
Italy	78,25	1,43%	1,43%	36,61	1,45%	1,49%
Latvia				1,49	0,06%	0,06%
Lithuania				2,51	0,10%	0,10%
Luxembourg				1,11	0,04%	0,05%
Netherlands	94,04	1,72%	1,71%	6,99	0,28%	0,28%
Poland	12,06	0,22%	0,22%	7,36	0,29%	0,30%
Portugal	8,42	0,15%	0,15%	4,00	0,16%	0,16%
Romania				0,27	0,01%	0,01%
Balkans	2,44	0,04%	0,04%			
Russia	23,38	0,43%	0,43%	10,65	0,42%	0,43%
Spain	95,47	1,74%	1,74%	42,84	1,69%	1,74%
Sweden	90,11	1,65%	1,64%	11,48	0,45%	0,47%
Switzerland	245,06	4,47%	4,47%	21,38	0,84%	0,87%
Turkey	6,13	0,11%	0,11%	2,97	0,12%	0,12%
UK	512,35	9,35%	9,34%	66,75	2,64%	2,71%
China	197,74	3,61%	3,64%	9,17	0,36%	0,37%
Taiwan	90,34	1,65%	1,66%			
India	64,05	1,17%	1,18%	17,89	0,71%	0,73%
Indonesia	15,15	0,28%	0,28%	25,11	0,99%	1,02%
Japan	486,60	8,88%	8,96%	261,92	10,34%	10,65%
South Korea	96,30	1,76%	1,77%	52,09	2,06%	2,12%
Malaysia	13,59	0,25%	0,25%	16,96	0,67%	0,69%
Philippines	6,60	0,12%	0,12%	5,07	0,20%	0,21%
Singapore	27,39	0,50%	0,50%	16,18	0,64%	0,66%
Thailand	20,69	0,38%	0,38%	2,09	0,08%	0,08%
Israel	10,54	0,19%	0,25%	0,23	0,01%	0,01%
United Arab Emirates	3,00	0,05%	0,07%			
Kuwait	1,32	0,02%	0,03%			
Egypt	3,71	0,07%	0,09%			
South Africa	36,78	0,67%	0,86%	21,14	0,83%	0,86%
Bloomberg Barclays Global-Aggregate Index				679	24,7%	24.7%
Total sum	**5459**	**99,68%**	**100%**	**2533**	**97,9%**	**100%**

7 Empirical Methods

7.1 *Simulated returns*

To investigate impact of the payout rule on sustainability of the Fund, we have used Matlab2019a to build a simulation model that uses 591 months of return observations from January 1970 through March 2019. The model extracts data from an input file which contains equity and bond returns, GDP growth component and inflation rates. The amount invested in each country in the portfolio was found by multiplying the initial Fund value with the asset allocation weight and the customized individual weight for each country. Important to note that while we omit Real estate investments in our replicating portfolio, the benchmark portfolio slightly changes and, in our case, consists of 70% in Equity, 20% in Sovereign bonds and 10% in Corporate bonds. Such benchmark is rather close to GPFG's target that limits investments into Equity to 70% and into bonds to 30%.

Having said that, the simulation process is starting. We simulate monthly returns for each asset class and country that are assumed to repeat precisely past portfolio returns (from January 1970 to March 2019), so that the return in, for example, July 2019 would be the same as the return in some random month out of previous 591 monthly observations. Such approach, though naive, but preserves cross-sectional dependence between asset classes and countries returns that tend to correlate. Moreover, we test the method by allowing both repetitions in returns across months, so that the random monthly returns may be picked several times across subsequent simulation and by forbidding such repetitions. In the latter case, the random monthly return from the past data may be picked only once for future simulation and then it has no chance to be repeated. Logically, in such a case, we would be limited in the number of monthly simulations to 591 months or about 48 years – that is exactly the number of overall collected previous monthly observations.

After each 12 months / 1 year of simulations, the model has to account for withdrawal required, transaction and management costs. A payout is withdrawn at the start of each year in accordance with the payout rule specified, – we test fixed payout, average payout, Ratchet and GDP rule one by one. Then, portfolio has to be rebalanced to the target benchmark specified above. We account for transaction costs by subtracting 10 basis points (0.1%) of the money transferred from actual year-end allocation to the desired benchmark. That is if the Fund has to reallocate 50 MM NOK to track its benchmark, the rebalancing costs would be 50 thousand NOK. Such rebalancing is done at the start of the year if annual portfolio returns deviates by more than 1.25% from the benchmark's return – this is the tracking error target set by the GPFG. Additionally, every year management fee is subtracted which amounts to 6 basis point of the Fund's value – average fee over the GPFG's history (1998 – 2018).

What is still missing is that for the GDP payout rule and for real values calculation, *(i)* GDP growth and *(ii)* inflation has to be projected. We are approaching this by different angle compared to the portfolio returns.

(i) Norwegian GDP has been growing on average by about 2.9% annually through 1970 to 2018. However, more recently from 2000 onwards, the growth has slowed to 1.6%. Hence, we project future GDP growth at moderate levels between 0% to 3% (95% confidence interval) with normal distribution (the mean would thus be close to 1.6%).

$$GDP\ growth\ \epsilon\ N(1.5\%,\ 0.75\%)$$

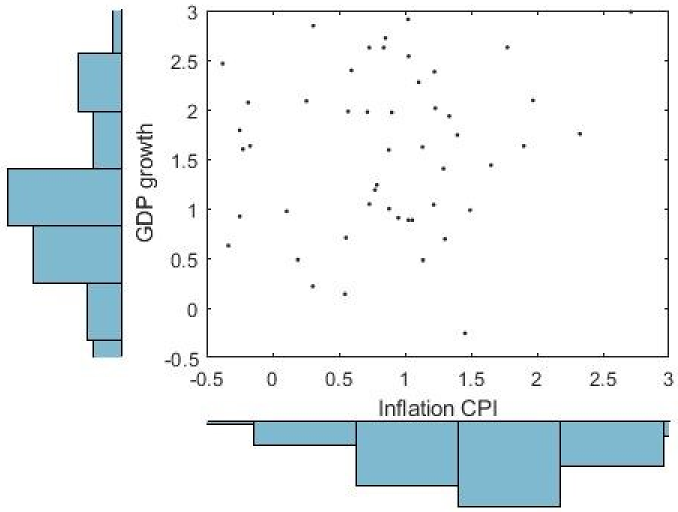
Just to remind that the GDP payout rule assumes payout of 7% of national GDP, which is the projected annual non-oil budget deficit, so that the more

GDP grows – the larger withdrawal would be requested.

(ii) As Norway is following inflation targeting, we cap annual inflation rate by 2.5% (the actual target of the Central Bank as of June 2019 is 2%, but small deviations are likely); in addition, historically (1970 – 2018) Norwegian annual GDP growth and annual CPI were positively correlated ($\rho \approx 0.3$). Hence, we would use simplified Cholesky technic to generate correlated with GDP growth random inflation rates capped at 2.5%:

$$Infl_i = \rho * GDP\ growth_i + \sqrt{1-\rho^2} * N(0,1) \ \leq 2.5\%$$

Figure 7.1. *Example of simulated dependent values of GDP growth and inflation*



7.2 *Historical simulations as an approach*

Historical simulation, which is also known as bootstrapping, is a procedure for predicting the value of a portfolio by using historical data to "simulate" asset returns over time. The main assumptions of this method are: *(i)* Chosen sample period can closely describe the properties of assets; There is a possibility of repeating the past in the future, i.e. we assume that there are patterns in the volatilities and correlations of the asset returns that are repeated over time.

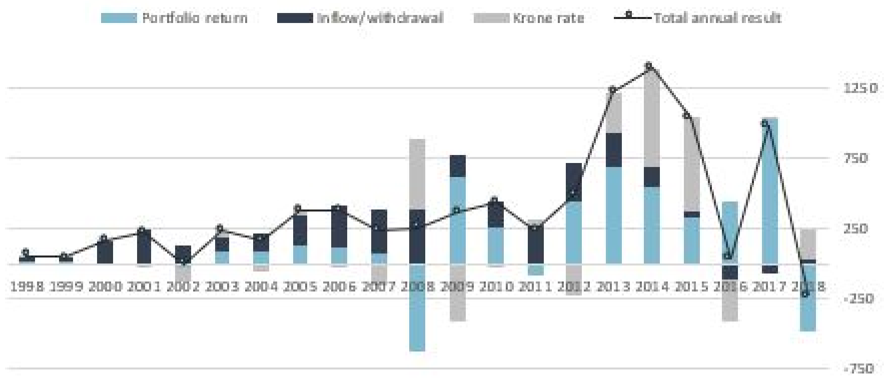
(ii) With a long enough series of data, this approach is considered effective for building reliable forecasts. It is also simple to implement. However, simplicity of this approach results in several disadvantages that we should consider while interpreting the obtained results: *(i)* Equally weighted approach used for all returns in the whole period "underweights" the recent past returns which have the most significant influence on the near future. Similarly, historical simulation neglects proper weighting of other important factors, such as inflation and GDP growth. *(ii)* Historical returns do not always serve well as a proxy for future security returns. In other words, a larger sample size might not guarantee a better forecast. Outliers like a financial crisis or a financial boom particularly poorly represent the future. On the other hand, there is no guarantee that these deviations will not be repeated (Jorion, 2007). What is indeed important to consider is the preservation of correlation across returns both in cross-sectional and time series dimensions. By using historical simulation approach, cross sectional correlation is likely to be preserved, while time dependence may be distorted – as prolonged sequence of negative returns after the financial crisis. Hence, to check the result for robustness, it is important to consider outcomes of, for instance, annual returns. If the probabilities across all three criteria remain close to the ones from monthly return simulations, we could be more confident about persistence of our results.

8 Historical performance of the Fund

8.1 *GPFG performance*

Before describing the core simulation results, it is worth to look back how the Fund has performed since its inception in 1998. The Fund's market value at the year end depends on three components: portfolio investment returns, inflow / payout during the year, influence of the currency exchange. Overall, the largest and most stable contributor to the GPFG used to be regular government inflows of oil revenues – on average 150 bn kroner per annum. However, this trend has reversed abruptly in 2016 with the withdrawal of about 105 bn kroner (Figure 7.1, Appendix D). As we mentioned, we model future Fund's value without consideration of possible inflows as the Fund's value has to be self-sustaining in the long run when oil revenues are expected to discontinue. Effects of Norwegian kroner depreciation could significantly enhance portfolio performance as evidenced by the net effect of NOK exchange of 702 bn kroner in 2014. It is easy to access currency effects ex post, however extremely hard to predict ex-ante. Hence, we model future portfolio returns based on past returns already adjusted for currency rate. In such a way, we would preserve to some degree the correlation between Norwegian currency and global GPFG's portfolio returns.

Figure 7.2. *Change in the Fund's market value (billions of kroner)*



8.1.1 *Portfolio performance*

The core point of this thesis is the sole portfolio performance and justified payout rate. In its first operating year, the Fund has invested only in fixed income instruments, while already in 1999, the investment horizon was expanded to equities. One recent major shift was the inclusion of unlisted real estate into the portfolio in 2011 (Figure 7.3, Appendix D). The investments into equities increased steadily over the GPFG's timeframe both in absolute and in relative terms. If in 2000, the share of equities in the portfolio was 40%, it increased to 66% already in 2018, and the new benchmark's target was capped at 70%. Real estate investments should not exceed 7% of the portfolio and currently account for 3%[13].

Figure 7.3. *The Fund's market value by asset class*

Out of 21 years of an operating history, the Fund has demonstrated negative returns only in 5 years (2001, 2002, 2008, 2011, and 2018) mostly connected to global economic downturns such as Dotcom bubble and Financial crisis of 2008-2009. Equities were the largest contributor to the overall returns with an average (arithmetic) return of around 7.25%. Fixed income average returns were at the level of 4.6% and returns for Unlisted real estate – 6.2%. As can be noted, broad diversification does not help the GPFG to avoid massive

[13]NBIM

equities result of -40.7% in 2008, moreover equites surprisingly underperformed S&P500 in 2018, when the Fund's investments into stocks declined by about 9.5% (Figure 7.4, Appendix E). Fixed income and Real estate investments were far more stable with average annual volatility of 3.7% and 5.5% accordingly (Table 5).

Figure 7.4. *Portfolio returns by components (1998 – 2018)*

Table 5. *Portfolio returns by components*

	Equity	Fixed income	Unlisted real estate
Arithmetic average return	7,25%	4,62%	6,18%
Geometric average return	5,31%	4,56%	6,05%
Standard deviation	19,55%	3,68%	5,45%

Overall, since inception, the Fund's average nominal return has been about 5.5% and net real return (after management costs) – 3.6%. The latter rate is an important analytical benchmark as the payout rate must be less than the real rate of return for the fund to stay sustainable. Despite diversification and conservative fixed income stance, returns are rather volatile with average standard deviation of around 7.4% (Table 6). Furthermore, a new strategy of larger participation in Equity markets and expansion into Real estate are expected to additionally increase return's standard deviation. Such anticipated increase in volatility together with recent fall in net real rates of return are the crucial quantitative reasons to test the sustainability of the NBIM's payout rate policy[14].

Table 6. *Historical performance of the GPFG*

	Since 01.01.1998	Last 15 years	Last 10 years	Last 5 years	Last 12 months
Fund return	5,47%	5,78%	8,33%	4,75%	-6,12%
Annual price inflation	1,77%	1,88%	1,69%	1,37%	1,70%
Annual management costs	0,08%	0,08%	0,07%	0,06%	0,05%
Net real return on fund	3,56%	3,74%	6,46%	3,27%	-7,74%
The fund's actual standard deviation	7,37%	7,87%	7,84%	6,39%	7,87%

[14]NBIM

9 Results

9.1 *Descriptive statistics*

Now is the time to turn to the replicated global portfolio with 591 monthly observations for Equities and Fixed income instruments. Over the observed timeframe from January 1970 to March 2019 the average monthly return for replicated global equities was 0.75%, for government bonds – 0.45%, and for corporate bonds – 0.43%. Given the current target GPFG allocation (70% in equities and about 30% in bonds), the weighted monthly return for such portfolio was equal to 0.66% or about 7.9% per annum (Table 7).

Table 7. *Replicated portfolio historical performance (monthly nominal returns, January 1970 – March 2019)*

Asset class	geometric mean	arithmetic mean	standard deviation
Equity	0,65%	0,75%	4,40%
Government bonds	0,43%	0,45%	1,84%
Corporate bonds	0,41%	0,43%	1,81%
Weighted (70% Equity, 20% gov. bonds, 10% corp. bonds)	0,59%	0,66%	0,10%

Next, it is necessary to observe how closely our collected global portfolio resembles actual portfolio of GPFG. As was discussed in Chapter 6, collected Equities data covers 99.6% of the Fund's Equity portfolio, while Fixed income covers 97.9%. However, GPFG from year to year has been changing weights to individual countries and selectively choosing corporate bonds, while we applied the same country weights estimated in 2018 across the whole portfolio and used Bloomberg Barclays corporate index as a proxy of corporate bonds portfolio. Hence, some deviations from the Fund's actual results are expected. Nevertheless, these discrepancies are limited, especially while looking at geometrical mean (Table 8). Estimated volatility of the replicated portfolio for Equities is less than for the actual portfolio, which could be explained by graduate shift of GPFG's investments into less risky markets.

Table 8. *Comparison of replicated portfolio and actual portfolio returns, 1998 – 2018*

	Equity		Fixed income	
	Replicated	Actual	Replicated	Actual
Arithmetic average return	6,63%	7,25%	4,80%	4,62%
Geometric average return	5,36%	5,31%	4,67%	4,56%
Standard deviation	16,52%	19,55%	5,24%	3,68%

Replicated nominal portfolio return, adjusted for inflation and management costs, is estimated at around 2.6% (since 1970) or 3.5% (since 1998), while actual portfolio return is equal to 3.6% (since 1998). Nevertheless, the real rate of return has fallen to 3.3% over the last five years (2013 – 2018) with a drastic fall of -7.7% in 2018. Consequently, current payout rule of 3% seems unsustainable over the long run, given such a small real rate of return and high volatility. The whole next chapter would be devoted to the analysis of empirical results.

9.2 *Results description*

Finally, the results of the analysis are presented below. Overall, we tested the sustainability of four payout rules (Table 9) in accordance with three criteria (Table 10). Our initial assumptions are illustrated below (Table 11). The simulations were extended to a 30-year period and to a 50-year period. For a 30-year period both with replacement and without replacement simulation approaches were applied (see p.50). Finally, the sensitivity analysis is presented and the analysis of results' consistency when using annual returns.

Table 9. *Payout rules*

Payout rule	Formulae
Fixed	$Spending_N = Spending\ rate(\cong 3\%) \times Asset\ mkt\ value_{N-1}$
Average	$Spending_N = Spending\ rate(\cong 3\%) \times \frac{1}{K}(Mkt\ value_{N-1} + Mkt\ value_{N-2} + \cdots + Mkt\ value_{N-K})$, K = 3 and 5
Ratchet	$Spending_N = \max_{N\in(0,T)}(Spending\ rate(\cong 3\%) \times Asset\ mkt\ value_{N-1},\ Spending_{N-1})$
GDP	$Spending_N = Spending\ rate(\cong 7\%) \times GDP_N$

Table 10. *Criteria tested*

Criteria	Formulae
First (Fund reduction)	$Prob(F_T < 0.75 * F_0) \mid Prob(F_T < 0.5 * F_0)$ $Prob(F_T < 0.75 * F_{Max}) \mid Prob(F_T < 0.5 * F_{Max})$, $where\ F_{Max} = \max_{t\in(0,T)} F_t$
Second (Payout reduction)	$Prob(\left(\frac{\sum_1^T W_t}{T}\right) < 237bn\ NOK)$
Third (Payout instability)	$\sigma(W_{t=10,t=20,t=30}) \geq 20\%$ $\sigma(\Delta W_{t,t+1}) \geq 20\%$

Table 11. *Criteria probability expectation*

Rule \ Criterion	First (Fund reduction)	Second (Payout reduction)	Third (Payout instability)
Fixed	moderate	high	high
Average	moderate	moderate	moderate
Ratchet	high	high	moderate
GDP	high	high	low / moderate

Table 12. *Criteria results for 30-year period (2019 – 2048) with replacement*

30-year with replacement		First (Fund reduction)				Second (Payout reduction)	Third (Payout instability)			
		From initial value (Dec 2018)		From maximum reached value			Payout cross-sectional / simulation			Change in payout
		by 25%	by 50%	by 25%	by 50%		10y	20y	30y	
		$Prob(F_T < 0.75 * F_0)$	$Prob(F_T < 0.5 * F_0)$	$Prob(F_T < 0.75 * F_{Max})$	$Prob(F_T < 0.5 * F_{Max})$	$Prob(\left(\frac{\sum_1^T W_t}{T}\right) < 237bn\ NOK)$	$\sigma(W_t) \geq 20\%$			$\sigma(\Delta W_{t,t+1}) \geq 20\%$
Fixed		0.7%	0.1%	13.0%	0.9%	2.7%	36.6%	53.7%	67.6%	11.3%
Average	3-year	1.0%	0.2%	12.1%	1.1%	4.6%	34.4%	51.4%	66.6%	6.4%
	5-year	1.3%	0.2%	14.0%	1.5%	4.5%	33.0%	52.6%	68.1%	4.8%
Ratchet		5.3%	2.4%	22.6%	5.9%	0.0%	32.6%	50.9%	65.9%	6.7%
GDP		3.8%	2.2%	10.2%	3.1%	0.0%	2.3%	3.4%	4.0%	1.1%

9.2.1 *30-year period (with replacement)*

Fixed payout rule

(i) First criterion

Given the fixed payout of 3% annually, there is a high chance that the Fund value would be preserved over the 30-year timeframe. For instance, the probabilities that the GPFG's portfolio value would drop by more than 25% and 50% compared to the value as of December 2018 are 0.7% and 0.1% respectively. The next two columns show probabilities of the same declines but from the maximum reached value. That is, the probabilities that the Fund's closing value in 2048 would be 25% (50%) or even smaller than the Fund's maximum end-of-year value over the 30-year period. As evidenced here, there is about 13% chance of fall by more than 25% over the time horizon. Therefore, under the current rule, the portfolio may have large declines.

(ii) Second criterion

The next criterion tests the probability that average payout over the next 30 years would be smaller than the current one of 237 bn NOK. There is only a little 2.7% chance of the future payout reductions.

(iii) Third criterion

Equally important is the stability of payouts, – excessive volatility could significantly impact government long-term financing needs and consumption patterns. We illustrate in the table both cross-sectional volatilities and volatility of change in annual payouts from year to year. Firstly, volatility of withdrawal across simulations at 10th, 20th and 30th forecasted year is shown. Uncertainty of the forecasts is growing the further in the future we project, so the standard deviations are rising – from 36.6% in 2028 to 67.6% in 2048. These high deviations illustrate that under fixed rule it is extremely hard for the Ministry of Finance to project payouts into the budget even over the next decade. Finally, payouts from year to year tend to be highly volatile as illustrated by 11.3% standard deviation of the annual change in payout.

Average rule

(i) First criterion

For both 3-year and 5-year average rule, there are similar chances of the Fund's value reduction. For example, only in 1.3% of simulations, the Fund's value in 2048 is 25% or more is smaller than in 2018 under the 5-year average rate. There is also a high 14% chance of general Fund's value decline by more than 25%.

(ii) Second criterion

Further, under average rate there are increasing chances, compared to Fixed rule, chances that the average annual payout value would be less than in 2018. Such negative outcome happens in 4.6% and 4.5% of simulations for 3- and 5-year average rule accordingly.

(iii) Third criterion

The major benefit of average rule should lie in higher predictability of its payouts as tested by the last criterion. However, the results show that cross-sectional volatility does not change much compared to the fixed rule: from 34.4% in 2028 to 66.6% in 2048 (3-year average rule). Future withdrawals are still highly volatile and depend on the future Fund's values. Nevertheless, volatility of changes in payouts drops significantly: 6.4% and 4.8% for average 3 and 5-year rules versus 11.3% for the fixed rule. Therefore, knowing an absolute payout in one year, it would be much easier for the government to forecast and maintain payouts in the future years.

Ratchet rule

(i) First criterion

The next Ratchet rule assumes non-declining withdrawals which makes it intuitively risky. As quantitatively supported, under such payout structure, there is about 5.3% chance of GPFG's value in 2048 fall below 75% of the GPFG's current value; and in 2.4% of simulations the value falls by 50%. In addition, there is 5.9% probability of Fund's value decline by more than 50% in 2048 from the GPFG's maximum value over the period from 2018 to 2048.

(ii) Second criterion

As payouts could not decline, there would no occurrence of average payout below current level (unless the Fund stops existing).

(iii) Third criterion

Property of non-declining payouts would diminish volatility of withdrawals as there would be years with exactly the same payouts. Nevertheless, this effect would be marginal. The cross-sectional standard deviation of payouts in 2028, 2038 and 2048 are 32.6%, 50.9%, and 65.9% accordingly. Cross-annual volatility of change in payout would be around 6.7%.

GDP rule

(i) First criterion

The final GDP rule imposes rather large spending rate of 7% of the GDP. Hence, there is rather high 3.8% chance of the Fund's value decline by more than 25% compared to the current value, and 2.2% chance of decline by more than 50%. There is also about 3.1% chance of Fund's value drop by more than 50% from the maximum reached value.

(ii) Second criterion

As GDP growth is mostly positive in our GDP simulation assumptions, there would be 0% chance of fall in average payout value – the same as for the Ratchet rule.

(iii) Third criterion

As GDP growth tends to be much smoother than the portfolio return, volatility of both cross-sectional payouts and their changes from year-of-year declines drastically. There is only 4.4% cross-simulation volatility of payouts in 30 years and only 1.1% annual change in payout volatility (same as for GDP growth).

Rules comparison

Fixed rule exhibits the smallest probabilities of Fund value decline compared to the current value (Figure 8.1). This is not surprising as the Fixed rule is the most flexible and thus adjusts quickly to the current state of the Fund. Contrary, Ratchet rule and GDP rule would imply high risk of Fund value declines as the payouts would not have downside adjustments. However, the latter two rules would treat current generations the most generously as payouts would increase or stay the same from year to year, though deteriorating future Fund value.

On the other hand, Fixed rule that adjusts quickly to the Fund value would demonstrate high volatility of payouts and their changes. This is very undesirable for budget purposes that target countercyclical and predictable payouts (high during recessions). For these purposes Average rule as evidenced by smaller volatilities (Third criterion) and GDP rule (smoother because of moderate GDP growth rate) is more favourable (Figure 8.3).

In conclusion, if the need in payouts for the budget financing is of less importance compared to the Fund's value preservation and wealth accumulation, Fixed rule has to be maintained. However, if the payouts and their predictability become more important for budgeting needs and external deficit financing is undesirable, more smooth GDP rule and Average rule shall be adopted.

Figure 8.1. *Results discussion (30-year with replacement): First criterion (Fund reduction)*

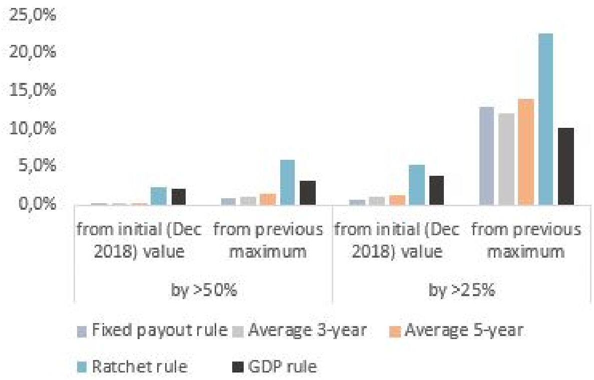
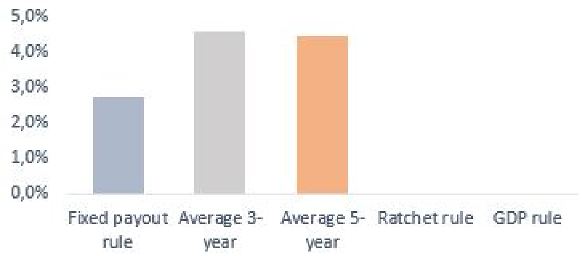


Figure 8.2. *Results discussion (30-year with replacement): Second criterion (Payout reduction)*



Next, we will briefly discuss the results for 30-year without replacement and 50-year simulations

9.2.2 *30-year period (without replacement)*

(i) First criterion

When we forbid repetitions of returns in the simulation, extremely negative returns (and positive) can occur only once. Given that negative returns have more influence on the portfolio than the positive ones (if value drops by 20% it needs 25% upside to reach the initial value), portfolio results in such case

Figure 8.3. *Results discussion (30-year with replacement): Third criterion (Payout stability)*

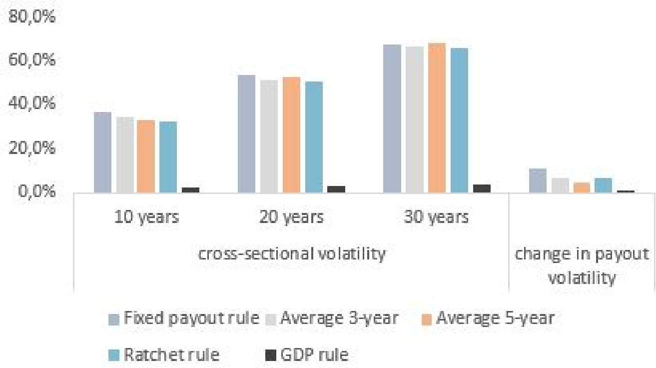


Table 13. *Criteria results for 30-year period (2019 – 2048) without replacement*

30-year without replacement	First (Fund reduction)				Second (Payout reduction)	Third (Payout instability)			
	From initial value (Dec 2018)		From maximum reached value			Payout cross-sectional / simulation			Change in payout
	by 25%	by 50%	by 25%	by 50%		10y	20y	30y	
	$Prob(F_T < 0.75 * F_0)$	$Prob(F_T < 0.5 * F_0)$	$Prob(F_T < 0.75 * F_{Max})$	$Prob(F_T < 0.5 * F_{Max})$	$Prob\left(\frac{\sum_1^T W_t}{T}\right) < 237bn\ NOK$	$\sigma(W_t) \geq 20\%$			$\sigma(\Delta W_{t,t+1}) \geq 20\%$
Fixed	0.5%	0.1%	5.4%	0.6%	2.1%	2.0%	2.8%	3.4%	11.0%
Average 3-year	0.2%	0.0%	4.4%	0.3%	1.3%	1.8%	2.7%	3.4%	4.9%
Average 5-year	0.2%	0.0%	4.5%	0.3%	1.3%	1.7%	2.7%	3.4%	4.9%
Ratchet	0.8%	0.1%	6.5%	0.7%	0.0%	1.6%	2.4%	3.7%	7.5%
GDP	0.2%	0.0%	4.8%	0.5%	0.0%	2.3%	3.3%	4.0%	1.1%

would be much more optimistic.

This is shown by extremely low probabilities of Fund reduction (by 25% from the 2018 value) – from 0.2% for the Average and GDP rule to 0.8% for the Ratchet rule. In general, the possibility of large Fund deterioration is again the largest for the Ratchet rule – 6.5%.

(ii) Second criterion

As previously, Fixed rule being the most responsive to the Fund value provides the most chances that the average payout would be less than the current one. It happens in 2.1% cases under the Fixed rule and in 1.3% of cases under the Average rule. The Ratchet and GDP rules again assume non-declining payouts.

(iii) Third criterion

As there would be limited number of returns to select from, especially in the final years, volatilities of payout decrease significantly. For instance, the standard deviation of withdrawals in 10 years does not exceed 2.3% and in 30 years – 4.0%. The lowest volatilities are under the Average rule that ties payout amount to the average of its past values. Simultaneously, lowest volatility of changes in payouts are under the GDP rule (1.1%) because of smooth GDP growth assumption, while the volatility of changes under Average rule is 4.9%.

9.2.3 ***50-year period (with replacement)***

(i) First criterion

Over the longer 50-year timeframe, results change in an interesting way. While Fixed rule being the most responsive to the Fund value outperform other rules in terms of Fund value preservation for 30 years period, over longer simulation Average rule produces better chances of preservation as

Table 14. *Criteria results for 50-year period (2019 – 2068) with replacement*

50-year with replacement		First (Fund reduction)				Second (Payout reduction)	Third (Payout instability)			
		From initial value (Dec 2018)		From maximum reached value			Payout cross-sectional / simulation			Change in payout
		by 25%	by 50%	by 25%	by 50%		10y	30y	50y	
		$Prob(F_T < 0.75 * F_0)$	$Prob(F_T < 0.5 * F_0)$	$Prob(F_T < 0.75 * F_{Max})$	$Prob(F_T < 0.5 * F_{Max})$	$Prob\left(\frac{\sum_1^T W_t}{T} < 237bn\ NOK\right)$	$\sigma(W_t) \geq 20\%$			$\sigma(\Delta W_{t,t+1}) \geq 20\%$
Fixed		0.4%	0.7%	15.0%	1.7%	1.3%	37.5%	68.5%	81.7%	11.3%
Average	3-year	0.4%	0.1%	13.2%	1.3%	1.7%	34.2%	66.9%	78.7%	6.5%
	5-year	0.3%	0.1%	11.2%	1.1%	1.6%	32.9%	68.3%	78.8%	5.1%
Ratchet		4.4%	3.2%	20.8%	7.6%	0.0%	32.8%	69.5%	80.1%	6.6%
GDP		4.5%	3.7%	9.9%	4.5%	0.0%	2.4%	4.0%	6.0%	1.3%

shown in the table above. In 2068 (forecast's final year) the probability of Fund value decline by more than 50% compared to 2018 is only 0.1% for the Average rule, whereas under the Fixed rule it is seven times higher – 0.7%. The Ratchet rule and the GDP rules are much less sustainable with about 4.5% chances of Fund's value decline by more than 25%, and 3.2% / 3.7% by more than 50%. Possibility of overall Fund's large deteriorations over the 50 years are also the smallest for the Average rule (chance of fall by 25% or more – 13.2% versus 15.0% for the Fixed rule).

(ii) Second criterion

Payouts do not decline under the Ratchet and GDP rule. In about 1300 out of 100 000 simulations their average value is smaller than the payout in 2018 (237 bn NOK), while for the Average rule these chances are higher but only marginally at 1.6% (3-year average) and 1.7% (5-year average).

(iii) Third criterion

Here, the cross-sectional volatility is shown for the 10th (2028), 30th (2048) and 50th (2068) simulation years. As with the 30-year period, payouts are the most predictable under the GDP rule both in terms of payouts volatility across simulations and through the years (1.3%). Across other rules payouts are highly volatile with the slight underperformance of the Fixed rule. In addition, the standard deviation of the change in payouts is the highest for the Fixed rule as well. On the other side, Average rule (in particular, 5-year average) demonstrate more than twice less standard deviation of such changes.

9.3 *Comparison and suggestions*

After testing different periods and rules, some of the conclusions can be made. we can present the summary of simulation results. First, the best performing rules across each criterion are presented below (Table 15), while the detailed ranking is given in Appendix G. The best performing in this context is the rule that has the smallest probability of Fund reduction by more than 25% or 50% (First criterion), Payout reduction (Second criterion) and the smallest volatility of payouts across simulations and volatility of changes in payouts across time (Third criterion).

Table 15. *Best performing rules across criteria*

	Fund value preservation / increase	Payout amount preservation / increase	Payout stability
30 year (until 2048)	Fixed rule / Average rule (3-year)	Ratchet rule / GDP rule	GDP rule / Average rule (5-year)
50 year (until 2068)	Average rule	Ratchet rule / GDP rule	GDP rule / Average rule (5-year)

As can be seen, Fixed rule being the most responsive to the Fund value by immediate payout adjustment, outperforms other rules in the Fund value preservation in a 30 years period. Nevertheless, over longer timeframe of 50 years, Average rule performs even better in protecting Fund value from large deterioration. Assuming non-declining payouts and mostly growing GDP, average payouts are the largest under the last two rules: Ratchet and GDP. In addition, closely tracking GDP growth, GDP rule payouts exhibit the smallest cross-sectional volatility and volatility of their changes.

Given the GPFG's objective of long-term wealth preservation, the first criterion is of the foremost importance. However, as the Fund gradually becomes a reliable source of non-oil budget deficit, the second and third criteria should gain more and more attention. By paying too much attention to the absolute amount of payout, the Ratchet rule and GDP rule seem to be detrimental for wealth protection. However, the Average rule being effective in long-run wealth preservation (first criterion), while still having rather stable payouts (Third criterion) is a viable alternative to the current 3% Fixed rule.

Next, to make the conclusions more justified, the sensitivities of results to the spending rate are illustrated. These sensitivities are shown only for the current Fixed rule and for the initially recommended Average rule. What we would like to see is whether a change in spending rate can simultaneously enlarge both payouts value and the Fund value. In other words, whether a smaller spending rate (current – 3%) can result in higher absolute payout through the Fund value enhancement, or vice versa, if higher spending rate can be allowed. The results of the value distribution are shown for the final year (2048) of the 30-year period simulation.

Table 16. *Fixed rule: Payout (nominal) amount distribution, 2048 year*

Spending rate	10 percentile	25 percentile	median	average	75 percentile	90 percentile
1%	280	420	653	808	1016	1508
2%	358	517	791	960	1206	1751
3%	380	552	832	1009	1257	1842
4%	374	539	831	1007	1264	1839
5%	358	520	790	965	1203	1777

Firstly, the results for the Fixed rule are presented. The current 3% spending rate payouts in 30 years outperforms other spending rules, which means that the current structure effectively protects the Fund value. Should the spending rate increase to 4% or 5%, the Fund's value in 30 years would be less to such extent that even higher spending percentage would not result in larger absolute withdrawal.

Table 17. *Average rule (3-year average): Payout (nominal) amount distribution, 2048 year*

Spending rate	10 percentile	25 percentile	median	average	75 percentile	90 percentile
1%	277	412	630	785	984	1453
2%	354	514	782	944	1183	1718
3%	360	521	788	952	1185	1731
4%	378	547	832	1014	1268	1855
5%	363	525	813	980	1229	1784

Table 18. *Average rule (5-year average): Payout (nominal) amount distribution, 2048 year*

Spending rate	10 percentile	25 percentile	median	average	75 percentile	90 percentile
1%	270	399	616	769	967	1435
2%	346	503	768	932	1167	1717
3%	375	540	824	996	1241	1805
4%	376	546	840	1024	1275	1874
5%	369	532	807	992	1248	1843

For the Average rule the picture is changing slightly. Here the largest payouts are provided by the 4% spending rate and 5-year average rate, so that more aggressive spending policy can be allowed. Moreover, withdrawals under such rate would be higher than under the Fixed rule as well.

Nevertheless, these conclusions might be biased by overoptimistic returns forecast. As the Fund's net real rate of return since inception was only about 3.6%, the spending rate intuitively must be below this rate to preserve the wealth. By throwing into simulations equity and fixed income returns from the 1970s when markets have been rising sharply, we could have created the overoptimistic scenario given that past is unlikely to be repeated in the future.

Given that the GPFG has decreased its spending rate to 3% recently, it is obvious that the NBIM would like to stick to that structure for some time and would be reluctant to change the payout rule and spending rate again. Hence, assuming 3% spending rate, the Fixed rule performs better than the Average rule as can be seen by payout value distribution (Table 16). Overall, should the Fund stay conservative and reluctant to more aggressive spending policy, 3% Fixed rule is recommended. In the case of more optimistic returns outlook and/or larger needs in payouts' budget financing, the shift to 4% spending rate can be implemented. However, in this situation, we would recommend changing simultaneously the payout policy to the Average rule that provides larger payouts (Table 17) together with smaller volatility of their year-to-year changes.

9.4 *Consistency of results*

Finally, it is necessary to check the performance of payout rules when the analysis is applied to annual return simulations, not monthly as before. If the results of criteria performance are similar, we can assume that a change in returns definition does not influence the consistency of results and that monthly returns simulation predicts future portfolio performance in an unbiased way.

For the annual returns we used the same observation time period from 1970 till 2018 and 30 year with replacement simulation approach. The source of data and returns calculation were precisely the same as for the monthly returns. Below the results across all three criteria are presented with the absolute difference (Δ) from monthly returns analogous results shown in the brackets (Table 19).

Table 19. *Criteria results for 30-year period (2019 – 2048) with replacement (Annual returns data)*

30-year with replacement		First (Fund reduction)				Second (Payout reduction)	Third (Payout instability)			
		From initial value (Dec 2018)		From maximum reached value			Payout cross-sectional / simulation			Change in payout
		by 25%	by 50%	by 25%	by 50%		10y	20y	30y	
		$Prob(F_T < 0.75 * F_0)$	$Prob(F_T < 0.5 * F_0)$	$Prob(F_T < 0.75 * F_{Max})$	$Prob(F_T < 0.5 * F_{Max})$	$Prob\left(\left(\frac{\sum_1^T W_t}{T}\right) < 237bn\ NOK\right)$	$\sigma(W_t) \geq 20\%$			$\sigma(\Delta W_{t,t+1}) \geq 20\%$
Fixed		0.5%	0.1%	12.4%	1.2%	1.8%	38.1%	55.0%	69.7%	12.3%
	Δ	(0.2%)	(0.0%)	(0.6%)	(0.3%)	(0.9%)	(1.5%)	(1.3%)	(2.1%)	(1.0%)
Average	3-year	0.5%	0.1%	11.7%	1.1%	4.2%	35.9%	54.6%	69.1%	6.9%
	Δ	(0.5%)	(0.1%)	(0.4%)	(0.0%)	(0.4%)	(1.5%)	(3.2%)	(2.5%)	(0.5%)
	5-year	0.5%	0.2%	12.2%	1.1%	4.0%	34.2%	54.2%	71.2%	5.4%
	Δ	(0.8%)	(0.0%)	(1.8%)	(0.4%)	(0.5%)	(1.2%)	(1.6%)	(3.1%)	(0.6%)
Ratchet		5.0%	0.8%	14.1%	3.2%	0.0%	34.2%	52.8%	70.6%	7.0%
	Δ	(0.3%)	(1.6%)	(3.2%)	(2.7%)	(0.0%)	(1.6%)	(1.9%)	(4.7%)	(0.3%)
GDP		3.5%	0.7%	6.9%	1.3%	0.0%	2.3%	3.3%	4.0%	1.4%
	Δ	(0.3%)	(1.5%)	(3.3%)	(1.8%)	(0.0%)	(0.0%)	(0.1%)	(0.0%)	(0.3%)

As can be seen, the differences for annual returns from monthly returns do not exceed 3.2% (First criterion), 0.5% (Second criterion), and 4.7% (Third criterion). The Ratchet rule tends to have the largest differences. Because of much smaller number of annual observations (49 years) compared to monthly data (591 months) and larger volatility of annual returns, simulation on monthly returns was chosen as the core one, however, differences in their results won't change previously made conclusions.

10 Conclusions

The key findings of this paper:

(i) Given an expected real return after management costs of 3.6%, the current Fixed 3% Payout rule is sustainable because it effectively protects the Fund value in a 30-year period.

(ii) Should the Fixed Payout rule increase to 4% or 5%, the Fund's value and absolute payouts would significantly diminish in a 30-year period. Thus, the payout rate must be lower than expected return rate to stay sustainable in the long run.

(iii) The 3% Average rule with a 5-year base being effective in long-run wealth preservation, while still producing stable payouts, is a viable alternative to the current 3% Fixed rule.

(iv) In the case of more optimistic expected returns and/or larger needs in payouts' budget financing, the shift to 4% Average Payout rule (5-year) is recommended because it provides larger payouts together with smaller volatility of their year-to-year changes in a 30-year period.

We find that the Payout rule is sustainable in both 30-and 50-year periods even when petroleum revenues are no longer transferred to the Fund. Therefore, as long as the GPFG holds its payout rate below expected real return on the Fund's portfolio, the endowment would stay sustainable in the long-run. Even though we could have created the overoptimistic scenario of the expected return by throwing into simulations asset returns from the 1970s, we still cannot reject our null hypothesis. Furthermore, our findings stay valid under both monthly and annual return simulations. We therefore can conclude that a change in returns definition does not influence the consistency of results and that monthly returns simulation predicts future portfolio performance in an unbiased way.

As it was anticipated earlier, the results of our analysis can be interpreted slightly differently depending on how evaluation criteria are prioritized and how much risk the Fund is willing to take. Yet, we think that some criteria are more important than others for the sustainability of the Fund. Given the GPFG's objective of long-term wealth preservation, the first criterion of preserving the purchasing power is of the greatest importance. However, as the Fund gradually becomes a reliable source of non-oil budget deficit, the second and third criteria should gain more and more attention. The Ratchet rule and GDP rule by paying too much attention to the absolute amount of payout seem to be harmful for wealth protection. In contrast, the Average rule being effective in long-run wealth preservation (First criterion), while still having rather stable payouts (Third criterion) is a viable alternative to the current 3% Fixed rule.

The results of our simulations are consistent with existing academic literature, which provides additional insight on the issue of payout rates. A large share of those studies argues that the average payout rate should be below the average expected return on the fund for two reasons: *(i)* if returns are variable, the rate of the Fund's growth will be less than the average expected return, and *(ii)* asset returns demonstrate long cycles over long horizons, with both extended period of average returns below and above the long-term average. Thus, by holding the withdrawal rate at 3% fixed rate or at 3% average rate with a 5-year average base, the Fund shall preserve its value going forward.

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Appendix A. Geographical distributions

Table A1. Regional composition of the fund's equity holdings

Region	Millions of kroner	Percent
North America	**2 243 147**	**40,9%**
United States	2 124 610	38,8%
Canada	118 537	2,2%
Europe	**1 864 921**	**34,0%**
United Kingdom	512 347	9,4%
France	278 329	5,1%
Germany	267 986	4,9%
Switzerland	245 059	4,5%
Spain	95 470	1,7%
Netherlands	94 037	1,7%
Sweden	90 114	1,6%
Italy	78 247	1,4%
Denmark	51 409	0,9%
Finland	41 459	0,8%
Belgium	34 987	0,6%
Asia	**1 094 288**	**20,0%**
Japan	486 598	8,9%
China	197 742	3,6%
South Korea	96 298	1,8%
Taiwan	90 340	1,6%
Hong Kong	69 236	1,3%
India	64 050	1,2%
Oceania	**123 695**	**2,3%**
Australia	116 938	2,1%
Latin America	**84 431**	**1,5%**
Brazil	53 451	1,0%
Africa	**43 234**	**0,8%**
South Africa	36 781	0,7%
Middle East	**25 043**	**0,5%**

Table A2. Sector composition of the fund's bond holdings

Currency	Millions of kroner	Percent
US dollar	1 157 451	43,5%
Euro	666 827	25,1%
Japanese yen	256 250	9,6%
British pound	109 355	4,1%
Canadian dollar	93 096	3,5%
Australian dollar	63 304	2,4%
South Korean won	43 299	1,6%
Mexican peso	40 599	1,5%
Swiss frank	28 668	1,1%
Brazilian real	23 284	0,9%
Indonesian rupiah	23 278	0,9%
Swediah krona	23 232	0,9%
South African rand	21 088	0,8%
Indian rupee	17 089	0,6%
Malaysian ringgit	16 958	0,6%
Singapore dollar	15 693	0,6%
Danish krone	12 771	0,5%
Russian ruble	10 649	0,4%
Colombian peso	9 649	0,4%
New Zealand dollar	8 216	0,3%
Polish zloty	6 034	0,2%
Philippine peso	5 065	0,2%
Turkish lira	2 966	0,1%
Thai baht	2 088	0,1%
Yuan renminbi	1 974	0,1%
Chilean peso	966	0,0%

Appendix B. Investment type distribution

Table A3. Sector composition of the fund's equity holdings

Sector	Millions of kroner	Percent
Financials	**1 299 103**	**23,7%**
Banks	524 912	9,6%
Real estate	288 280	5,3%
Insurance	266 309	4,9%
Financial services	219 601	4,0%
Industrials	**708 762**	**12,9%**
Industrial goods and services	592 560	10,8%
Construction and materials	116 202	2,1%
Technology	**689 838**	**12,6%**
Consumer goods	**653 764**	**11,9%**
Personal and household goods	267 455	4,9%
Food and beverage	241 557	4,4%
Automobiles and parts	144 751	2,6%
Health care	**626 847**	**11,4%**
Consumer services	**589 709**	**10,8%**
Retail	312 757	5,7%
Travel and leisure	154 347	2,8%
Media	122 605	2,2%
Oil & Gas	**320 756**	**5,9%**
Basic materials	**271 304**	**5,0%**
Chemicals	150 430	2,7%
Basic resources	120 874	2,2%
Telecommunications	**163 344**	**3,0%**
Telecommunications	163 344	3,0%
Utilities	**155 333**	**2,8%**

Table A4. Sector composition of the fund's bond holdings

Sector	Millions of kroner	Percent
Government bonds	**1 433 456**	**53,9%**
Government-related bonds	**336 579**	**12,7%**
Agencies	159 691	6,0%
Local authorities	110 036	4,1%
Supranational	57 409	2,2%
Sovereign	9 443	0,4%
Inflation-linked bonds	**139 396**	**5,2%**
Corporate bonds	**609 314**	**22,9%**
Industrials	313 046	11,8%
Financials	252 867	9,5%
Utilities	43 401	1,6%
Securitised bonds	**141 105**	**5,3%**
Covered bonds	141 105	5,3%

Appendix C. Customized weights estimation

Table A5. Equity portfolio

Country	Invested	Actual Weight	Coefficient	New Weight
Brazil	53,45	0,98%	1,0000	0,98%
Chile	7,42	0,14%	1,0000	0,14%
Colombia	3,93	0,07%	1,0000	0,07%
Canada	118,54	2,16%	1,0000	2,16%
Mexico	17,74	0,32%	1,0000	0,32%
Peru	1,89	0,03%	1,0000	0,03%
US	2124,61	38,79%	1,0000	38,79%
SUM America	**2327,58**	**42,50%**		**42,50%**
Actual America		42,50%		
Coefficient America		1,0000		
		Europe		
Belgium	34,99	0,64%	0,9986	0,64%
Finland	41,46	0,76%	0,9986	0,76%
France	278,33	5,08%	0,9986	5,07%
Ireland	6,33	0,12%	0,9986	0,12%
Italy	78,25	1,43%	0,9986	1,43%
Netherlands	94,04	1,72%	0,9986	1,71%
Austria	12,39	0,23%	0,9986	0,23%
Portugal	8,42	0,15%	0,9986	0,15%
Spain	95,47	1,74%	0,9986	1,74%
Germany	267,99	4,89%	0,9986	4,89%
Denmark	51,41	0,94%	0,9986	0,94%
Poland	12,06	0,22%	0,9986	0,22%
Russia	23,38	0,43%	0,9986	0,43%
United Kingdom	512,35	9,35%	0,9986	9,34%
Switzerland	245,06	4,47%	0,9986	4,47%
Sweden	90,11	1,65%	0,9986	1,64%
Czechia	0,32	0,01%	0,9986	0,01%
Turkey	6,13	0,11%	0,9986	0,11%
SUM Europe	**1864,81**	**34,05%**		**34,00%**
Actual Europe		34,0%		
Coefficient Europe		0,9986		
		Middle East and Africa		
United Arab Emirates	3,00	0,05%	1,2791	0,07%
Egypt	3,71	0,07%	1,2791	0,09%
Israel	10,54	0,19%	1,2791	0,25%
South Africa	36,78	0,67%	1,2791	0,86%
SUM Middle East and Africa	**55,67**	**1,02%**		**1,30%**
Actual Middle East and Africa		1,30%		
Coefficient Middle East and Africa		1,2791		
		Asia & Oceania		
Australia	116,94	2,14%	1,0082	2,15%
Phillipinnes	6,60	0,12%	1,0082	0,12%
Hong Kong	69,24	1,26%	1,0082	1,27%
India	64,05	1,17%	1,0082	1,18%
Indonesia	15,15	0,28%	1,0082	0,28%
Japan	486,60	8,88%	1,0082	8,96%
China	197,74	3,61%	1,0082	3,64%
Malaysia	13,59	0,25%	1,0082	0,25%
New Zealand	6,76	0,12%	1,0082	0,12%
Singapore	27,39	0,50%	1,0082	0,50%
South Korea	96,30	1,76%	1,0082	1,77%
Taiwan	90,34	1,65%	1,0082	1,66%
SUM Asia & Oceania	**1211,38**	**22,12%**		**22,30%**
Actual Asia & Oceania		22,30%		
Coefficient Asia & Oceania		1,0082		
SUM World	**5459,44**	**99,68%**		**100%**

Table A6. Fixed income portfolio

Country	Invested	Actual Weight	Coefficient	New Weight
Government & Government Related Bonds (incl. Inflation-linked bonds)				
Australia	54,72	2,16%	1,03	2,23%
New Zealand	6,35	0,25%	1,03	0,26%
Brazil	23,46	0,93%	1,03	0,95%
Chile	1,98	0,08%	1,03	0,08%
Mexico	46,18	1,82%	1,03	1,88%
Colombia	11,00	0,43%	1,03	0,45%
USA	651,99	25,74%	1,03	26,51%
Canada	97,44	3,85%	1,03	3,96%
Austria	15,55	0,61%	1,03	0,63%
Belgium	19,97	0,79%	1,03	0,81%
Croatia	0,20	0,01%	1,03	0,01%
Cyprus	0,49	0,02%	1,03	0,02%
Czechia	0,33	0,01%	1,03	0,01%
Denmark	11,26	0,44%	1,03	0,46%
Finland	14,51	0,57%	1,03	0,59%
France	64,97	2,56%	1,03	2,64%
Germany	171,68	6,78%	1,03	6,98%
Hungary	0,55	0,02%	1,03	0,02%
Iceland	0,98	0,04%	1,03	0,04%
Ireland	7,54	0,30%	1,03	0,31%
Italy	36,61	1,45%	1,03	1,49%
Latvia	1,49	0,06%	1,03	0,06%
Lithuania	2,51	0,10%	1,03	0,10%
Luxembourg	1,11	0,04%	1,03	0,05%
Malta	0,15	0,01%	1,03	0,01%
Netherlands	6,99	0,28%	1,03	0,28%
Poland	7,36	0,29%	1,03	0,30%
Portugal	4,00	0,16%	1,03	0,16%
Russia	10,65	0,42%	1,03	0,43%
Slovakia	3,92	0,15%	1,03	0,16%
Slovenia	4,76	0,19%	1,03	0,19%
Spain	42,84	1,69%	1,03	1,74%
Sweden	11,48	0,45%	1,03	0,47%
Switzerland	21,38	0,84%	1,03	0,87%
Turkey	2,97	0,12%	1,03	0,12%
UK	66,75	2,64%	1,03	2,71%
China	9,17	0,36%	1,03	0,37%
India	17,89	0,71%	1,03	0,73%
Indonesia	25,11	0,99%	1,03	1,02%
Japan	261,92	10,34%	1,03	10,65%
Malaysia	16,96	0,67%	1,03	0,69%
Philippines	5,07	0,20%	1,03	0,21%
Singapore	16,18	0,64%	1,03	0,66%
Korea	52,09	2,06%	1,03	2,12%
Israel	0,23	0,01%	1,03	0,01%
South Africa	21,14	0,83%	1,03	0,86%
SUM	**1854,23**	**73,20%**		**75,40%**
Actual G&GR		**75,40%**		
SUM G&GR		73,20%		
Coefficient		103%		
Corporate & Securitized Bonds				
Bloomberg Barclays Global-Aggregate Index		29,70%	1,00	29,70%
Actual Corporate and Sovereign bonds		**29,70%**		**29,70%**

Appendix D. The Fund composition

Table A7. Change in the Fund's market value

Year	Total annual result	Portfolio return	Inflow/withdrawal	Krone rate
2018	-233	-485	29	224
2017	978	1028	-65	15
2016	35	447	-105	-306
2015	1044	334	42	668
2014	1393	544	147	702
2013	1222	692	239	291
2012	504	447	276	-220
2011	234	-86	271	49
2010	437	264	182	-8
2009	365	613	169	-418
2008	257	-633	384	506
2007	235	75	314	-153
2006	385	124	288	-28
2005	383	127	220	36
2004	171	82	138	-49
2003	237	92	104	41
2002	-5	-29	125	-101
2001	227	-9	251	-15
2000	164	6	150	8
1999	51	23	24	3
1998	58	12	33	13

Table A8. The Fund's market value by asset class

Year	Total	Equity	Fixed income	Unlisted real estate
2018	8256	5477	2533	246
2017	8488	5653	2616	219
2016	7510	4692	2577	242
2015	7475	4572	2668	235
2014	6431	3940	2350	141
2013	5038	3107	1879	52
2012	3816	2336	1455	25
2011	3312	1945	1356	11
2010	3077	1891	1186	
2009	2640	1644	996	
2008	2275	1129	1146	
2007	2019	958	1061	
2006	1784	726	1058	
2005	1399	582	817	
2004	1016	416	600	
2003	845	361	484	
2002	609	231	378	
2001	614	246	363	
2000	386	153	227	
1999	222	94	129	
1998	172	70	102	

Appendix E. GDFG Portfolio performance

Table A9. Returns decomposition

Year	Fund	Equity	Fixed income	Unlisted real estate
2018	-6,12%	-9,49%	0,56%	7,53%
2017	13,66%	19,44%	3,31%	7,52%
2016	6,92%	8,72%	4,32%	0,78%
2015	2,74%	3,83%	0,33%	9,99%
2014	7,58%	7,90%	6,88%	10,42%
2013	15,95%	26,28%	0,10%	11,79%
2012	13,42%	18,06%	6,68%	5,77%
2011	-2,54%	-8,84%	7,03%	-4,37%
2010	9,62%	13,34%	4,11%	
2009	25,62%	34,27%	12,49%	
2008	-23,31%	-40,71%	-0,54%	
2007	4,26%	6,82%	2,96%	
2006	7,92%	17,04%	1,93%	
2005	11,09%	22,49%	3,82%	
2004	8,94%	13,00%	6,10%	
2003	12,59%	22,84%	5,26%	
2002	-4,74%	-24,39%	9,90%	
2001	-2,47%	-14,60%	5,04%	
2000	2,49%	-5,82%	8,41%	
1999	12,44%	34,81%	-0,99%	
1998	9,26%		9,31%	

Appendix F. Portfolio simulation

Table A10. Example of portfolio annual rebalancing effect

	Before annual rebalancing			After annual rebalancing		
Year	Equity	Sovereign bonds	Corporate bonds	Equity	Sovereign bonds	Corporate bonds
2018	0,684	0,211	0,105	0,684	0,211	0,105
2019	0,697	0,227	0,108	0,700	0,200	0,100
2020	0,709	0,223	0,100	0,700	0,200	0,100
2021	0,754	0,186	0,092	0,700	0,200	0,100
2022	0,691	0,237	0,104	0,700	0,200	0,100
2023	0,627	0,275	0,129	0,700	0,200	0,100
2024	0,722	0,221	0,089	0,700	0,200	0,100
2025	0,720	0,208	0,104	0,700	0,200	0,100
2026	0,687	0,215	0,130	0,700	0,200	0,100
2027	0,725	0,206	0,100	0,700	0,200	0,100
2028	0,724	0,213	0,095	0,700	0,200	0,100
2029	0,757	0,180	0,095	0,700	0,200	0,100
2030	0,684	0,227	0,121	0,700	0,200	0,100
2031	0,769	0,157	0,106	0,700	0,200	0,100
2032	0,737	0,194	0,100	0,700	0,200	0,100
2033	0,765	0,179	0,087	0,700	0,200	0,100
2034	0,735	0,195	0,102	0,700	0,200	0,100
2035	0,759	0,176	0,096	0,700	0,200	0,100
2036	0,727	0,192	0,113	0,700	0,200	0,100
2037	0,716	0,217	0,098	0,700	0,200	0,100
2038	0,754	0,187	0,092	0,700	0,200	0,100
2039	0,685	0,236	0,110	0,700	0,200	0,100
2040	0,737	0,199	0,096	0,700	0,200	0,100
2041	0,710	0,204	0,118	0,700	0,200	0,100
2042	0,763	0,174	0,095	0,700	0,200	0,100
2043	0,737	0,200	0,095	0,700	0,200	0,100
2044	0,740	0,190	0,101	0,700	0,200	0,100
2045	0,708	0,216	0,108	0,700	0,200	0,100
2046	0,690	0,236	0,106	0,700	0,200	0,100
2047	0,703	0,226	0,102	0,700	0,200	0,100
2048	0,732	0,204	0,096	0,700	0,200	0,100

*Target benchmark – Equity 70%, Sovereign fixed income – 20%, Corporate fixed income – 10%

Table A11. Fund value distribution across 100’000 simulations (without Real estate investments)

	Percentile					
Year	10	25	median 50	mean	75	90
2018	**8010**	**8010**	**8010**	**8010**	**8010**	**8010**
2019	7250	7765	8435	8452	9071	9703
2020	7106	7928	8845	8880	9707	10677
2021	7145	8203	9289	9379	10420	11687
2022	7072	8354	9824	9886	11220	12876
2023	7150	8624	10170	10396	11967	14001
2024	7108	8681	10780	10956	12754	14870
2025	7304	8871	11111	11505	13597	16397
2026	7457	9184	11715	12089	14334	17292
2027	7475	9470	12009	12716	15312	18538
2028	7383	9673	12533	13349	16131	20444
2029	7737	10004	13134	14052	17180	21569
2030	7670	10330	13671	14815	17943	23447
2031	7880	10698	14028	15528	18954	25034
2032	8268	10926	14688	16310	19809	26254
2033	8449	11352	15296	17150	21139	28188
2034	8613	11769	15876	17870	21838	29492
2035	8905	12045	16688	18772	23157	31307
2036	9173	12549	17582	19867	24596	33383
2037	9517	12905	18053	20827	25806	34425
2038	9835	13282	19045	21904	27484	36093
2039	10186	13876	19965	22905	28819	38437
2040	9991	14139	20833	23967	29907	40875
2041	10507	14799	21600	25246	31912	44474
2042	10536	15543	22539	26587	32701	47554
2043	10673	16181	23875	27766	34372	48491
2044	11214	16601	24511	29388	36884	51067
2045	11791	17017	25646	30893	38314	53500
2046	12232	17698	26844	32303	39998	57038
2047	12451	18525	28365	34081	42351	60118
2048	12917	19041	29459	35934	44850	64911

Table A12. Payout nominal value distribution across 100’000 simulations (without Real estate investments)

	Percentile					
Year	10	25	median 50	mean	75	90
2018	**240**	**240**	**240**	**240**	**240**	**240**
2019	225	242	261	262	281	300
2020	220	244	273	276	304	334
2021	220	249	285	290	326	368
2022	220	253	298	305	349	398
2023	221	258	308	318	368	430
2024	223	264	322	335	391	464
2025	227	272	336	350	413	495
2026	231	280	350	368	435	530
2027	235	291	364	386	459	569
2028	240	298	378	405	485	604
2029	245	307	394	426	513	647
2030	250	317	413	447	540	684
2031	255	329	428	469	569	724
2032	261	339	449	493	597	773
2033	265	351	471	517	631	823
2034	272	362	493	543	660	874
2035	279	376	510	570	696	943
2036	286	386	533	601	739	1000
2037	292	401	557	630	778	1065
2038	301	412	580	660	815	1113
2039	310	429	606	693	856	1168
2040	317	440	635	728	902	1240
2041	328	455	664	766	954	1334
2042	341	472	692	803	1000	1393
2043	351	486	715	841	1051	1487
2044	361	502	748	883	1105	1589
2045	369	523	777	925	1159	1661
2046	384	541	806	969	1208	1750
2047	395	565	843	1015	1271	1844
2048	407	587	880	1065	1347	1928

Table A13. Payout real value distribution across 100’000 simulations (without Real estate investments)

	Percentile					
Year	10	25	median 50	mean	75	90
2018	**240**	**240**	**240**	**240**	**240**	**240**
2019	223	239	258	259	278	296
2020	213	236	264	267	294	323
2021	211	239	273	279	313	353
2022	213	245	288	295	337	385
2023	213	249	297	307	355	414
2024	215	254	310	322	377	447
2025	214	256	317	330	389	467
2026	219	265	332	349	412	503
2027	220	273	342	363	431	534
2028	222	275	350	375	448	558
2029	229	287	368	398	480	605
2030	233	296	385	417	504	639
2031	236	305	396	434	527	670
2032	239	310	410	451	546	707
2033	241	319	428	470	573	747
2034	246	328	446	491	597	791
2035	253	341	463	517	632	855
2036	257	346	478	538	663	896
2037	259	355	494	559	690	944
2038	265	362	510	580	716	978
2039	270	374	529	605	747	1019
2040	281	391	563	646	801	1100
2041	289	401	586	676	842	1177
2042	301	416	610	708	882	1228
2043	307	425	624	735	919	1300
2044	312	433	646	762	955	1372
2045	321	456	677	806	1010	1447
2046	330	465	693	834	1039	1505
2047	342	490	730	880	1102	1599
2048	353	510	763	925	1169	1674

Table A13. Payout intertemporal volatility distribution across 100'000 simulations

Year	Fixed rule	Average rule K=3	Average rule K=5	Ratchet rule	GDP rule
2019	0,112	0,058	0,058	0,096	0,007
2020	0,163	0,087	0,088	0,131	0,010
2021	0,203	0,144	0,111	0,160	0,013
2022	0,237	0,187	0,131	0,189	0,015
2023	0,263	0,224	0,175	0,216	0,016
2024	0,287	0,254	0,211	0,241	0,018
2025	0,307	0,282	0,242	0,260	0,019
2026	0,330	0,306	0,271	0,282	0,021
2027	0,352	0,329	0,297	0,304	0,022
2028	0,375	0,350	0,321	0,323	0,024
2029	0,397	0,370	0,344	0,341	0,025
2030	0,415	0,389	0,366	0,363	0,026
2031	0,430	0,407	0,387	0,381	0,027
2032	0,450	0,424	0,407	0,399	0,028
2033	0,465	0,441	0,427	0,423	0,029
2034	0,478	0,458	0,444	0,440	0,030
2035	0,495	0,474	0,461	0,458	0,031
2036	0,516	0,488	0,477	0,475	0,032
2037	0,533	0,504	0,494	0,492	0,033
2038	0,544	0,521	0,510	0,506	0,033
2039	0,566	0,539	0,528	0,528	0,034
2040	0,582	0,557	0,547	0,544	0,035
2041	0,597	0,575	0,567	0,563	0,036
2042	0,627	0,593	0,586	0,580	0,037
2043	0,631	0,610	0,604	0,597	0,037
2044	0,633	0,629	0,620	0,624	0,038
2045	0,647	0,646	0,636	0,642	0,039
2046	0,655	0,665	0,652	0,656	0,040
2047	0,663	0,682	0,669	0,669	0,040
2048	0,670	0,695	0,686	0,681	0,041

Table A14. Change in payout volatility distribution across 100'000 simulations

	Fixed rule	Average rule K=3	Average rule K=5	Ratchet rule	GDP rule
10	0,094	0,048	0,036	0,044	0,010
25	0,103	0,055	0,041	0,056	0,011
median 50	0,113	0,063	0,048	0,067	0,012
mean	0,113	0,063	0,049	0,066	0,012
75	0,123	0,071	0,056	0,078	0,012
90	0,133	0,079	0,063	0,086	0,013