NORGES BANK
INVESTMENT MANAGEMENT

Stress testing

Standard risk measures, such as volatility of returns, may not fully capture the potential impact of extreme events. Norges Bank Investment Management therefore supplements such measures with stress testing as a part of the investment risk framework. Stress tests aim to quantify potential losses in highly adverse scenarios in order to evaluate the portfolio's resilience. The fund conducts multiple forms of stress testing including historical stress testing and hypothetical, also known as predictive, stress testing. Historical stress testing uses changes in drivers of market risk such as equity prices, interest rates and real estate prices during historically stressed periods applied to the current portfolio to evaluate the impact of these events on the value of the fund. As a part of historical stress testing, we compute expected shortfall, which measures average loss of the portfolio in the worst q percent of outcomes. Hypothetical stress testing supplements subjective views with historical data to define shocks to a core set of systematic risk factors for a given scenario and mapping these risk factors to the current portfolio holdings to calculate the impact on the fund.

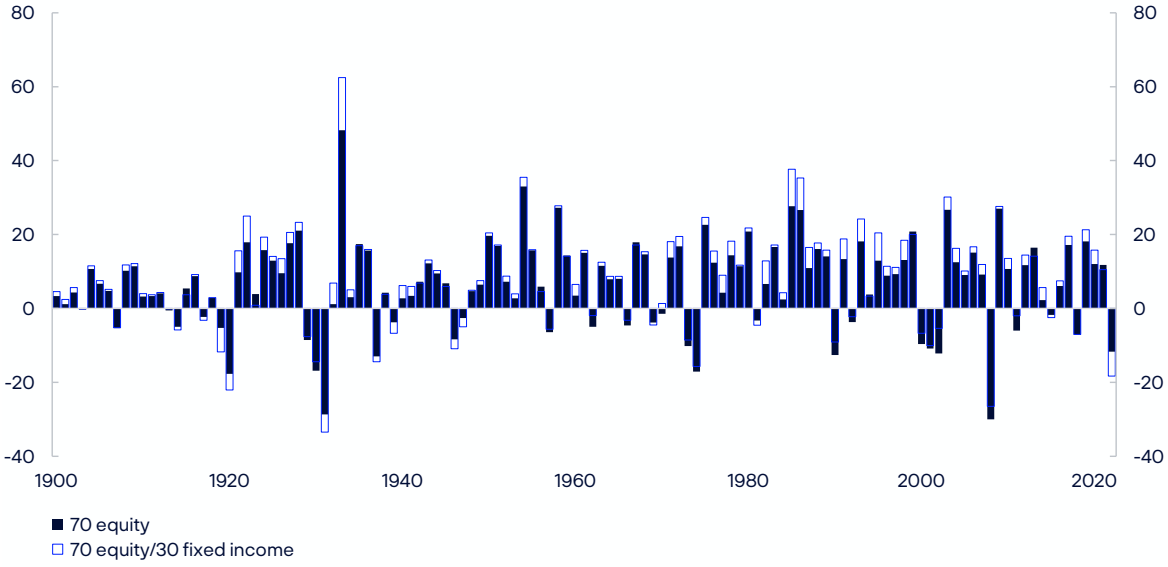
Historical stress tests

This section shows returns from historically stressed periods for the current asset composition of the fund. The section starts with an analysis of a stylised version of the fund's portfolio of global equities and bonds for a long historical sample. Then, historical simulations for the fund's positions at the end of 2023 are presented, using a model that covers all current investments. The section both includes simulated returns for specific historical scenarios as well as expected shortfall for various confidence levels.

Long historical sample

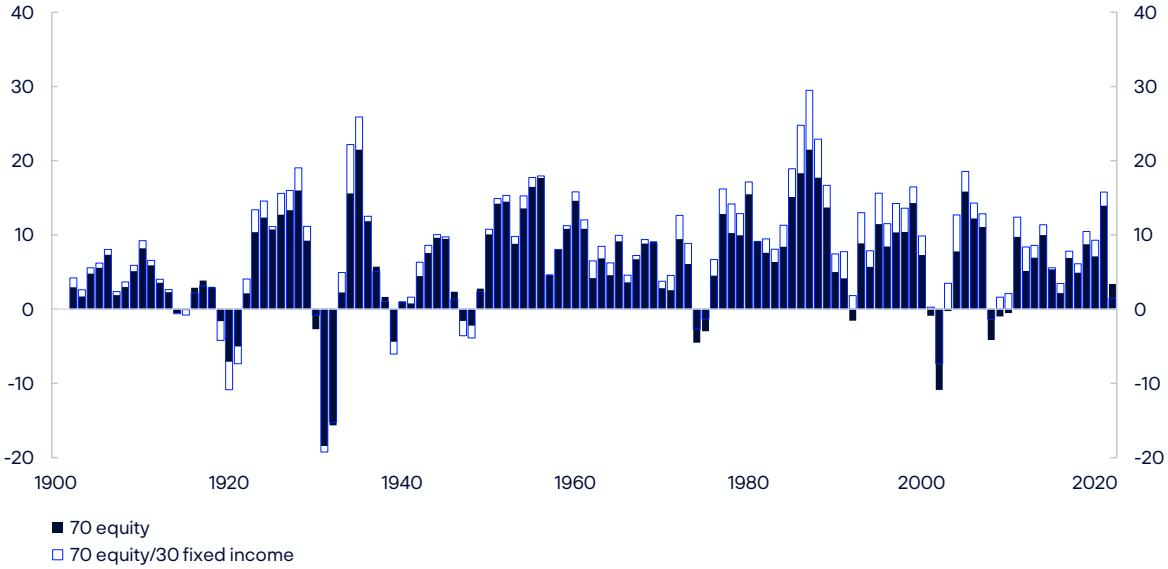
Chart 1-4 show rolling annualized returns over one, three, five and ten-year periods for a hypothetical portfolio made up of a fixed allocation of 70 percent equities and 30 percent fixed income. The returns are measured in US dollars and go back to 1900, covering more than 100 years of annual returns.

Chart 1 Annual return of 70 equity/30 fixed income. Measured in dollars. Percent.



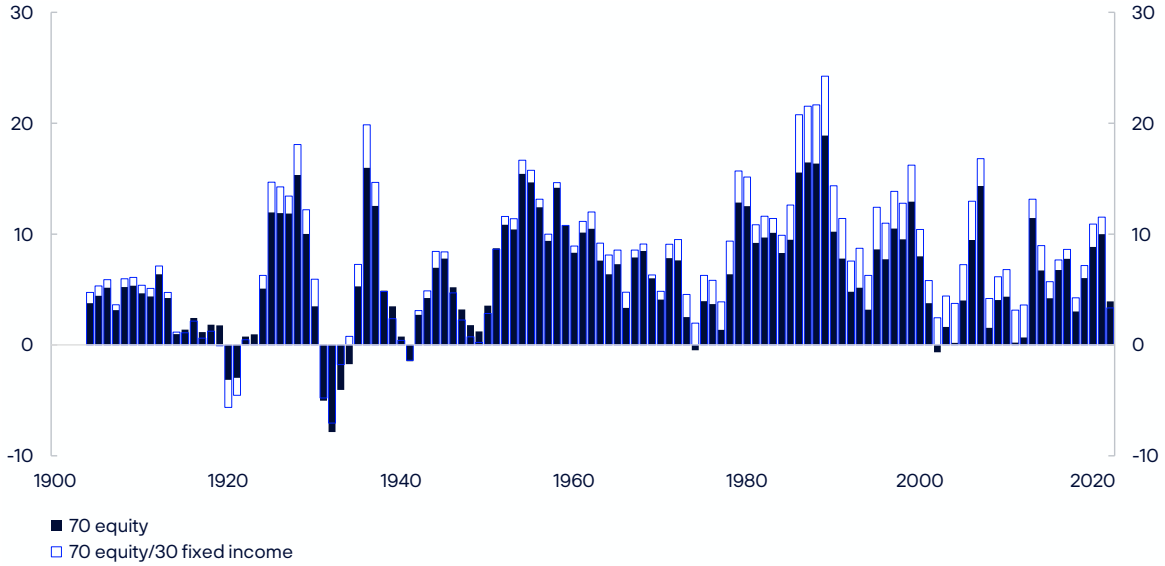
Source: Dimson-Marsh-Staunton global return data

Chart 2 Annualised 3-year rolling return of 70 equity/30 fixed income. Measured in dollars. Percent.



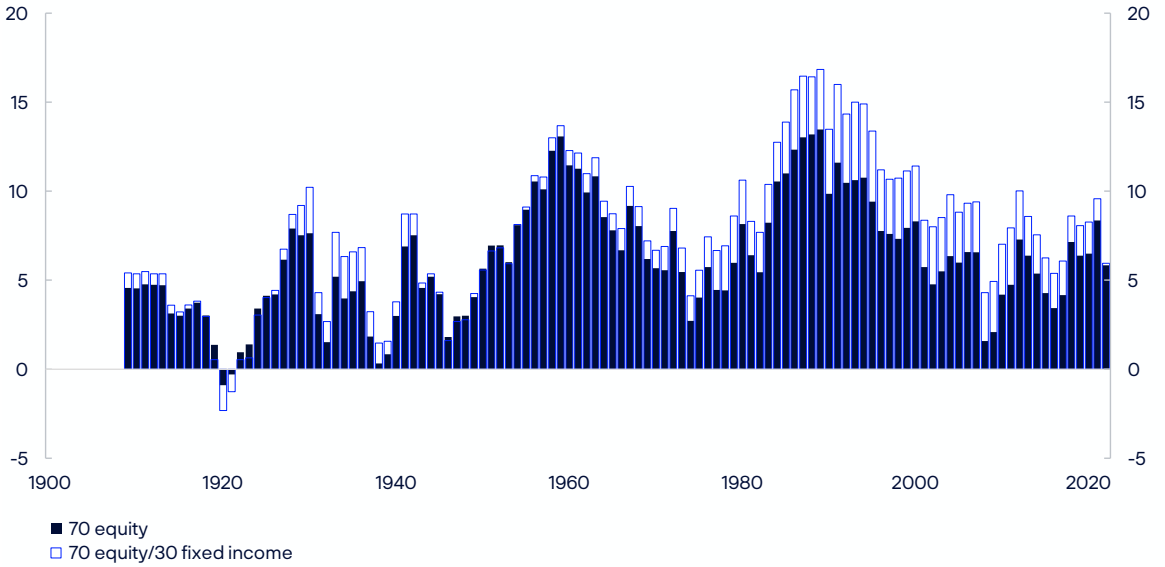
Source: Dimson-Marsh-Staunton global return data

Chart 3 Annualised 5-year rolling return of 70 equity/30 fixed income. Measured in dollars. Percent.



Source: Dimson-Marsh-Staunton global return data

Chart 4 Annualised 10-year rolling return of 70 equity/30 fixed income. Measured in dollars. Percent.



Source: Dimson-Marsh-Staunton global return data

Historical scenarios

Table 1 shows simulated portfolio returns for a selection of widely reported on events since May 1997. Results are shown both for the fund as well as equity and fixed-income management.

Table 1 Historical simulations of event returns for the fund, equity management and fixed-income management as at 31 December 2023, measured in the currency basket. Returns in percent of entity NAV.

Event	First date	Last date	Numbers of months	Fund	Equity manage-ment	Fixed income manage-ment
Asian financial crisis	01.07.1997	31.12.1997	6	7.61%	8.81%	3.72%
Russian default	01.08.1998	30.09.1998	2	-7.56%	-12.28%	3.95%
Dot com crash 1	01.09.2000	31.03.2001	7	-7.72%	-12.33%	3.39%
9/11	01.09.2001	30.09.2001	1	-8.30%	-12.09%	0.53%
Dot com crash 2	01.01.2002	30.09.2002	9	-11.69%	-18.95%	5.23%
Global Financial Crisis	01.05.2008	28.02.2009	10	-29.77%	-40.82%	0.75%
Euro debt crisis	01.04.2011	30.11.2011	8	-4.06%	-7.82%	5.15%
Taper Tantrum	01.05.2013	31.08.2013	4	2.94%	6.06%	-4.13%
Oil price decline	01.07.2014	31.12.2014	6	5.81%	6.92%	2.18%
EM slowdown	01.06.2015	30.09.2015	4	-6.10%	-8.97%	0.30%
Brexit referendum	01.06.2016	30.06.2016	1	-0.32%	-1.19%	1.77%
Volatility spike	01.09.2018	31.12.2018	4	-8.78%	-12.28%	-0.20%
Covid pandemic	01.02.2020	31.03.2020	2	-13.36%	-18.57%	0.35%
DM rate hike	01.01.2022	30.09.2022	9	-18.04%	-19.05%	-14.52%

Absolute expected shortfall

Chart 5-8 show the fund's expected shortfall for multiple tail probabilities using weekly historical simulations since January 2007. The chart also shows sensitivity to the choice of reporting currency. Whereas the Norwegian kroner depreciated in several past crises, other currencies appreciated. This analysis highlights how a stressed scenario where the Norwegian krone does not depreciate increases expected tail risk.

Chart 5 Expected shortfall of actual portfolio as at 31 December 2023. Confidence level 90%. Percent.

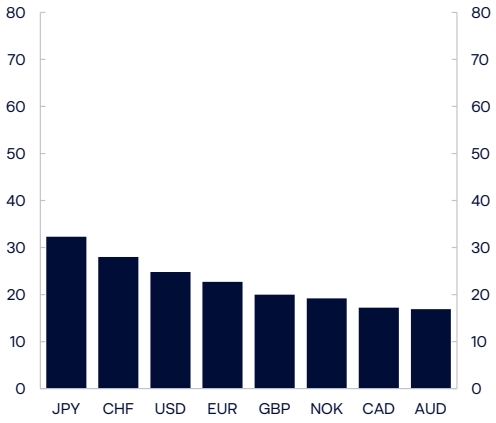


Chart 6 Expected shortfall of actual portfolio as at 31 December 2023. Confidence level 95%. Percent.

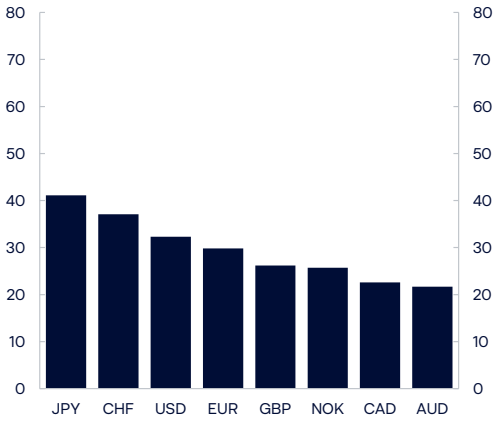


Chart 7 Expected shortfall of actual portfolio as at 31 December 2023. Confidence level 97.5%. Percent.

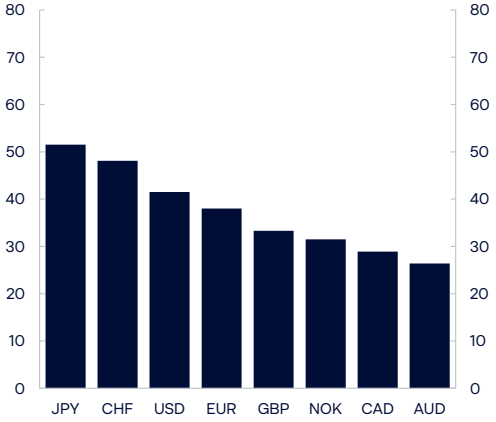
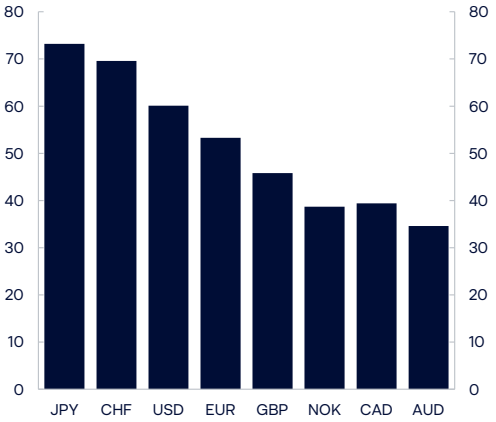


Chart 8 Expected shortfall of actual portfolio as at 31 December 2023. Confidence level 99%. Percent.



Hypothetical stress tests: Systematic risk factors

An important drawback of historical simulations is that future crises may play out differently than in the historical periods covered by the model. To explore the performance of the fund's portfolio under a range of adverse macroeconomic scenarios, Norges Bank Investment Management performs scenario-based forward-looking stress tests.

The selection of scenarios is informed by key topics that have the potential to shape the macro environment over the next years. We choose three out of a longer list of stressed events that could have a large adverse impact on the fund's portfolio. Our choice is based on, among other things, extremes and imbalances in return drivers and key macro variables. The list of three scenarios therefore evolves from year to year and is shaped by world affairs, macro-economic conditions, and movements in asset prices.

Since our previous stress test published in January 2023, important market moves have been:

- Declining realized and expected inflation
- Increasing real rates
- Increasing term premiums
- Compression of equity risk premiums
- Major economies avoided a recession that was highly anticipated at the start of 2023.

In last year's stress test, we considered the following scenarios, all against a backdrop of high levels of government debt:

1. De-anchored inflation expectations
2. Hard landing
3. Geopolitical conflict

None of the scenarios materialised over the last year. This is not surprising given that all three scenarios refer to extreme outcomes that have a relatively low probability of occurring, especially over shorter horizons. However, it is still useful to discuss them in retrospect.

Sharp tightening of monetary policy in all major markets prevented an inflationary environment from settling in and de-anchoring long-horizon inflation expectations. The hard landing has not materialised either, despite the rapid increase in real interest rates. There is a risk that this is not over yet: high levels of public debt combined with high real interest rates pose a challenge for governments and investors. The combination of high public debt and high government bond yields constrains fiscal and monetary policy. Under such conditions, recessions tend to be more protracted. The negative shock to risky assets originating from higher real interest rates has so far been softened by a large decline in the equity risk premium, which reached lows last seen more than two decades ago.

Geopolitical tensions continue to shape the world. The geopolitical conflict scenario considered in the last year's report was modelled as a major regional military conflict, where international relations break down in a sudden and unpredictable way. The risk of a major physical conflict is still there. However, this year we introduce a major geopolitical tension that takes the shape of a drawn-out economic conflict. This event has a higher probability attached to it than the conflict we modelled last year, and we will focus on such a scenario in this year's

stress test. Specifically, with the world becoming more divided, we see increased risk that two separate blocks of adversaries are formed with restrictions on flow of goods, services, and capital.

Given this backdrop, we consider the following three scenarios:

Debt crisis
Persistently high real interest rates and debt trigger a deep and protracted recession. Public and private sector balance sheets are stretched. Interest rate sensitive sectors with relatively higher leverage are hit particularly hard, with a crisis in real estate being one of the features. The ensuing recession is protracted for both developed and emerging markets. High levels of public debt limit the ability of governments to combat the recession.

Repricing of risk
Equity risk premiums are currently at historically low levels. A shallow recession triggers equity risk premiums to normalise to slightly above historical levels. The hit to equity cash flows is relatively transitory. Inflation does not go down all the way to central bank targets, leaving central banks having to manage a difficult trade-off between fighting inflation and stimulating growth.

Divided world
Tensions between countries increase, resulting in a protracted policy-driven geoeconomic conflict that leads to decoupling. The decoupling has a negative and persistent impact on output growth. At the same time, the decoupling (e.g., re-shoring and near-shoring) leads to higher inflation. Trade and capital flows between the two economic blocks decline permanently. Due to the competition between the two blocks, there will be increased investments into strategic sectors.

To estimate the portfolio impact under the three scenarios outlined above, we translate the narratives into shifts in the following return drivers: dividend growth, equity risk premium, inflation expectations, real rates, term premium and liquidity premium. Our starting point for creating scenarios is the current market pricing for each return driver. Each scenario is created through a particular combination of shifts in return drivers. The shifts in return drivers are informed by a combination of relevant historical episodes, auxiliary models and economic intuition, with the goal of ensuring economic consistency. Next, we estimate the exposures of each asset class to the return drivers listed above. We then combine shifts in return drivers with the estimated exposures to obtain the portfolio impact for each asset class. The portfolio impact represents the change in portfolio value over a 3-5 year horizon. Drawdowns could be more or less severe in the short run.

The key takeaways from portfolio impact presented in Table 2:

- Equities are vulnerable under each scenario; this is partly driven by currently high valuations.
- Downside risk in fixed income has decreased over the last two years following a sharp increase in real rates.
- The fund is still exposed to geopolitical risk, and even economic tensions can lead to large losses.

Table 2 Hypothetical scenario impact for GPFG portfolio as at 31 December 2023.

	Exposure	Shock			Impact		
	Billions of kroner	Percent			Billions of kroner		
	Market Value	Debt crisis	Repricing of risk	Divided world	Debt crisis	Repricing of risk	Divided world
Equities in local currency							
Developed markets - small cap	886	-56	-46	-49	-495	-406	-431
Developed markets - large cap	8,835	-48	-39	-42	-4,225	-3,468	-3,680
Emerging and Frontier markets	1,133	-39	-24	-31	-444	-275	-352
Total in local currency	**10,854**	**-48**	**-38**	**-41**	**-5,164**	**-4,150**	**-4,463**
Fixed income in local currency							
Developed markets - short term treasuries	957	0	1	-1	5	13	-6
Developed markets - long term treasuries	1,776	0	4	-4	6	68	-63
Developed markets - government related	407	0	4	-3	2	18	-14
Developed markets - corporates	1,283	0	3	-4	-2	43	-47
Emerging markets	87	-1	2	-2	-1	1	-2
Total in local currency	**4,510**	**0**	**3**	**-3**	**10**	**144**	**-131**
Real Assets in local currency							
Listed real estate	308	-43	-32	-41	-133	-100	-125
Unlisted real estate	333	-18	-13	-17	-59	-44	-56
Unlisted infrastructure	25	-1	-4	-2	0	-1	0
Total in local currency	**666**	**-29**	**-22**	**-27**	**-192**	**-144**	**-182**
Total in local currency	**15,765**	**-34**	**-26**	**-30**	**-5,346**	**-4,150**	**-4,776**

Note: Small cap and large cap are based on benchmark definitions. Long term treasuries include maturities of 3 years or more. Corporates include securitized bonds. Unlisted assets show gross asset value for exposure and listed real estate only includes equity exposure. Derivates are mapped to the relevant asset class. The totals include cash.

Table 2 reports the portfolio impact in local currency, which does not include the effect of Norwegian kroner. Table 3 translates the portfolio impact in local currency to the portfolio impact in Norwegian kroner. The kroner has the tendency to depreciate under most of the scenarios we consider. The depreciation mitigates the portfolio impact when translated to Norwegian kroner. It is conceivable that the depreciation effect will dissipate over time. Under such circumstances, the portfolio impact in Norwegian kroner will be more closely aligned with the portfolio impact in local currency.

Table 3 Hypothetical scenarios, impact from currencies for GPFG portfolio as at 31 December 2023.

	Billions of kroner	Shock			Impact		
		Percent			Billions of kroner		
	Market Value	Debt crisis	Repricing of risk	Divided world	Debt crisis	Repricing of risk	Divided world
Portfolio impact in local currency	15,765	-34	-26	-30	-5,346	-4,150	-4,776
Currency impact – developed markets	14,640	1	4	2	138	640	276
Currency impact – emerging markets	1,125	0	3	1	-3	29	10
Portfolio impact in NOK	**15,765**	**-33**	**-22**	**-28**	**-5,212**	**-3,481**	**-4,490**

Relative expected shortfall

The Executive Board has set a mandate limit for expected stressed relative loss versus the fund's benchmark index. The fund is to be managed in such a way that the annual expected shortfall does not exceed 3.75 percentage points. Table 4 shows relative expected shortfall for the fund as well as each of the fund's investment strategies.

Table 4 Expected shortfall relative to benchmark of investment strategies as at 31 December 2023. Each strategy measured stand-alone with the other strategies positioned in-line with the benchmarks. All numbers measured at fund level in the fund's currency basket. Basis points.

	Expected shortfall price history since 01.01.2007
Market exposure	18
Asset positioning	18
Security selection	41
Internal security selection	38
External security selection	19
Fund allocation	105
Real estate	112
Unlisted real estate	43
Listed real estate	81
Renewable energy infrastructure	7
Allocations	34
Total	**108**