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 map these risk factors to the current portfolio holdings to calculate the impact on the fund.

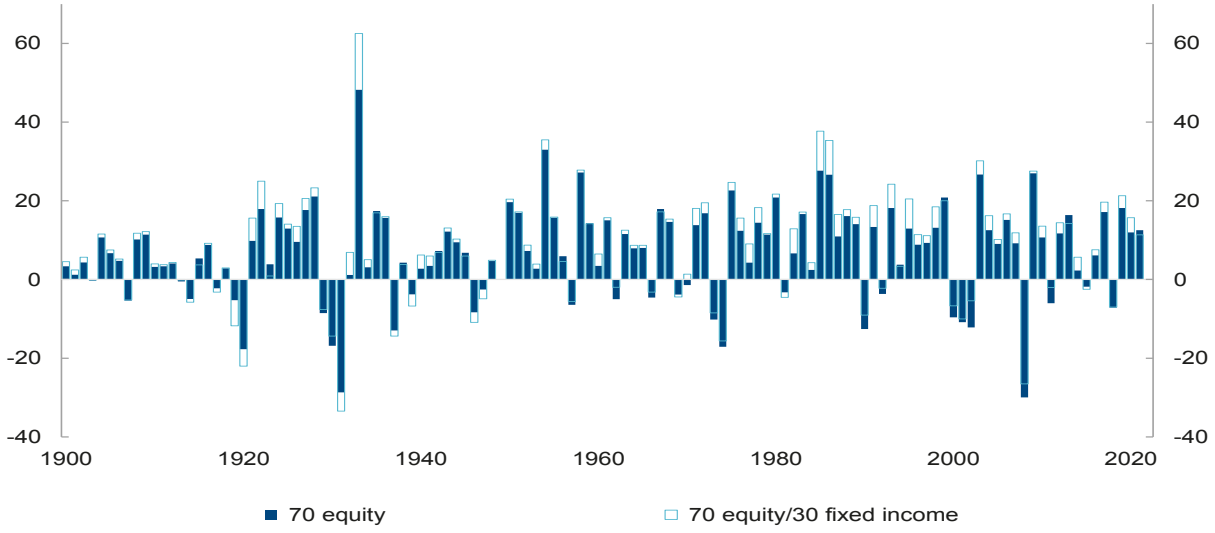
Historical stress tests

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 2022 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

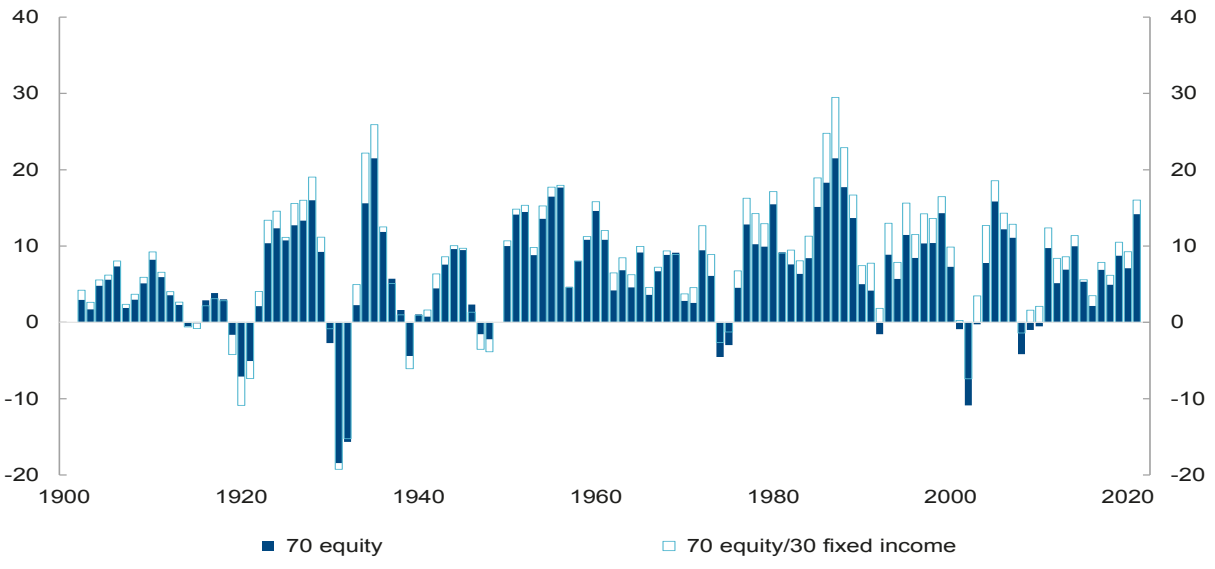
Chart 1-4 show rolling annualized returns over one, three, five and ten-year periods for a hypothetical portfolio made up of a fixed allocation of 70 percent equities and 30 percent fixed income. The returns are measured in US dollars and go back to 1900, covering more than 100 years of annual returns.

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



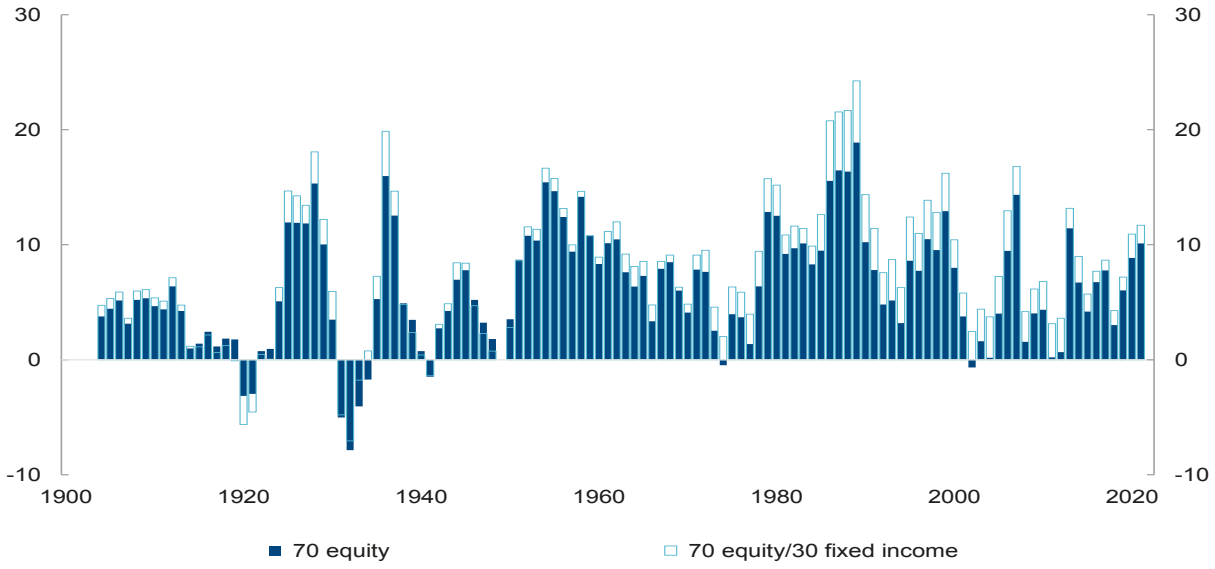
Source: Dimson-Marsh-Staunton global return data

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



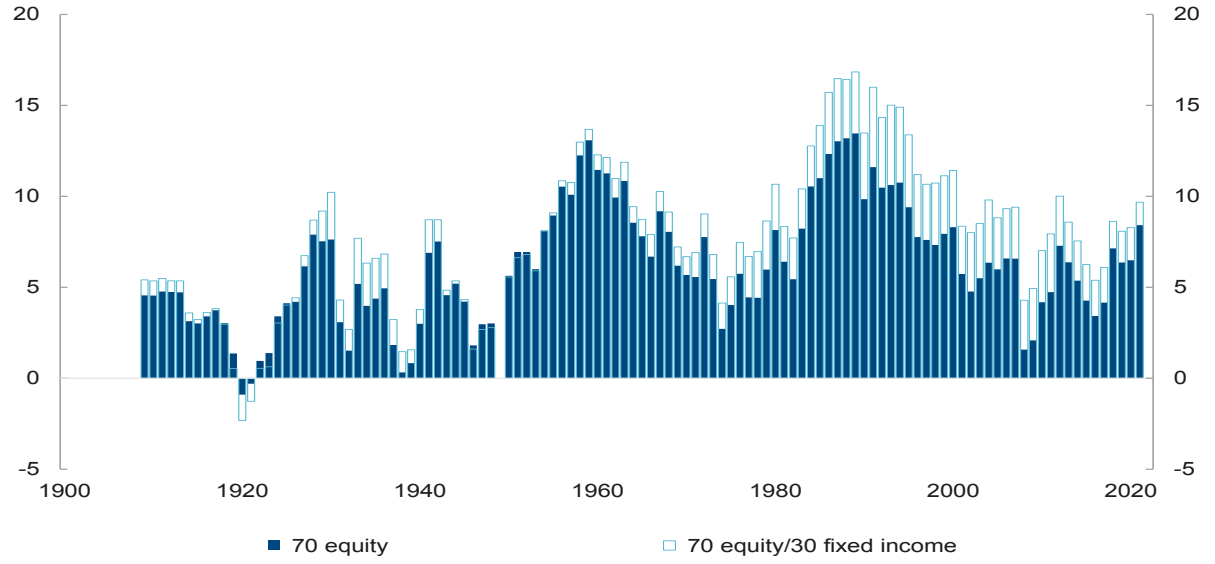
Source: Dimson-Marsh-Staunton global return data

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 2022, 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	6.23%	6.89%	3.50%
Russian default	01.08.1998	30.09.1998	2	-7.80%	-12.78%	3.67%
Dot com crash 1	01.09.2000	31.03.2001	7	-6.07%	-10.62%	3.35%
9/11	01.09.2001	30.09.2001	1	-7.65%	-11.23%	0.50%
Dot com crash 2	01.01.2002	30.09.2002	9	-11.03%	-18.01%	4.67%
Global Financial Crisis	01.05.2008	28.02.2009	10	-29.67%	-40.62%	1.05%
Euro debt crisis	01.04.2011	30.11.2011	8	-4.33%	-8.09%	4.63%
Taper Tantrum	01.05.2013	31.08.2013	4	2.40%	5.12%	-3.95%
Oil price decline	01.07.2014	31.12.2014	6	5.56%	6.69%	2.15%
EM slowdown	01.06.2015	30.09.2015	4	-6.63%	-9.92%	0.27%
Brexit referendum	01.06.2016	30.06.2016	1	-0.24%	-1.06%	1.80%
Volatility spike	01.09.2018	31.12.2018	4	-8.31%	-11.46%	-0.20%
Covid pandemic	01.02.2020	31.03.2020	2	-13.60%	-18.75%	0.15%
DM rate hike	01.01.2022	30.09.2022	9	-16.66%	-17.19%	-13.85%

Absolute expected shortfall

Chart 5–8 show the fund's expected shortfall for multiple tail probabilities using weekly historical simulations since January 2007. The figure 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 2022. Confidence level 90%. Percent.

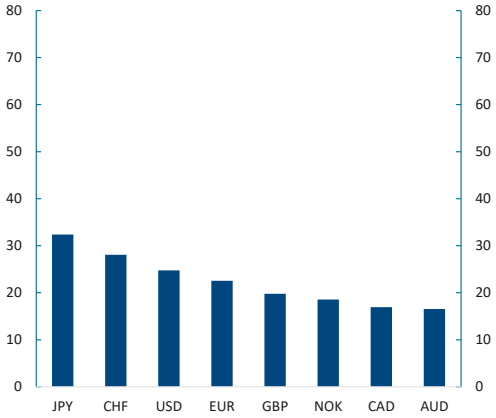


Chart 6 Expected shortfall of actual portfolio as at 31 December 2022. Confidence level 95%. Percent.

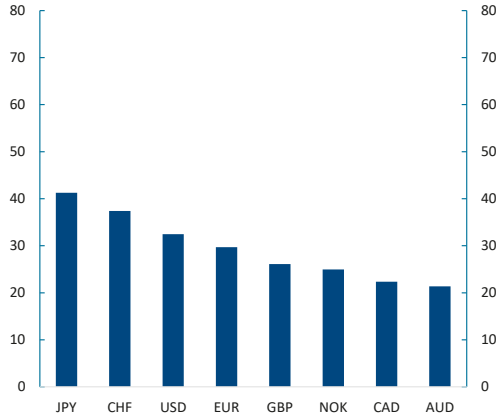


Chart 7 Expected shortfall of actual portfolio as at 31 December 2022. Confidence level 97.5%. Percent.

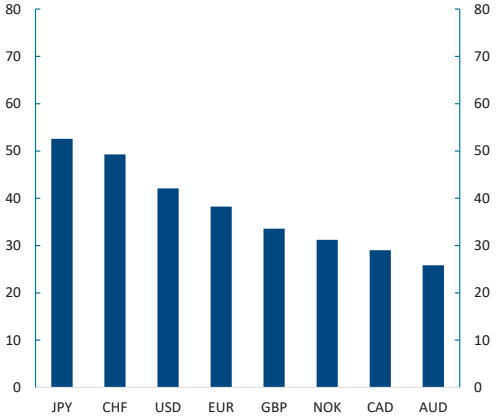
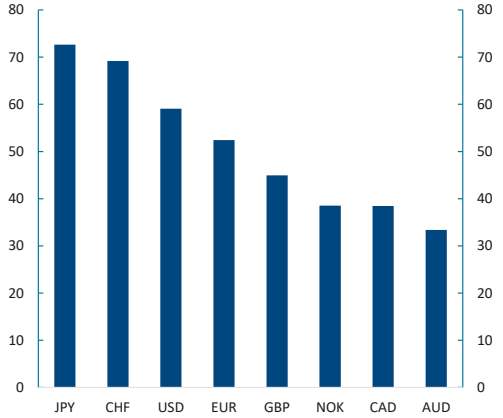


Chart 8 Expected shortfall of actual portfolio as at 31 December 2022. Confidence level 99%. Percent.



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 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. These are a de-anchoring of long-term inflation expectations, a hard landing, and a rise in geopolitical tensions, all against a backdrop of high levels of government debt.

De-anchored inflation expectations
Despite the recent sharp increase in inflation across all major markets, long-term inflation expectations remain anchored. Under this scenario, we assume that central banks stop tightening monetary policy prematurely. Reacting to high inflation in a challenging macro environment with high levels of public debt and slowing output growth, central banks are either unable or unwilling to bring inflation fully under control. This results in long-term inflation expectations gradually increasing to around 4 percent in key developed markets. Dividend growth expectations fall as companies lose pricing power because of de-anchored inflation expectations.

Hard landing
Real rates increase to multi-decade highs. High levels of debt and slowing output growth in major economies makes governments and companies ill-prepared for persistently high levels of real rates. The increase in real rates leads to a deep recession, with equity cash flows taking a hit. High levels of public debt also limit the scope for fiscal stimulus, which contributes to the severity of the recession. Tight monetary policy brings inflation back close to target.

Geopolitical conflict
This scenario looks at the impact of a major geopolitical conflict which sets in motion a decoupling of trade and financial links in the global economy. The decoupling generates a significant hit to equity cash flows through declines in output growth. Initially, the conflict triggers large spikes in risk premiums, reflecting the decline in output and repricing of risk. Along with fiscal expansion, this is followed by a persistent increase in inflation expectations and poor real returns on government bonds. The increase in inflation expectations is driven by the combination of the decline in global trade and fiscal expansion.

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 fund's portfolio exposures and shock impact for each market segment are shown in table 2.

Table 2 Hypothetical scenario impact for GPFG portfolio as at 31 December 2022.

	Exposure	Shock			Impact		
	Billions of kroner	Percent			Billions of kroner		
	Market Value	De-anchored inflation exp.	Hard landing	Geo-political conflict	De-anchored inflation exp.	Hard landing	Geo-political conflict
Equities in local currency							
Developed markets - small cap	734	-49	-27	-62	-359	-198	-456
Developed markets - large cap	6,760	-41	-23	-53	-2,774	-1532	-3,554
Emerging and Frontier markets	946	-30	-16	-64	-280	-154	-601
Total in local currency	**8,440**	**-40**	**-22**	**-55**	**-3,413**	**-1,885**	**-4,611**
Fixed income in local currency							
Developed markets - short term treasuries	966	-1	0	-1	-5	-3	-6
Developed markets - long term treasuries	1,275	-6	-7	-3	-79	-90	-44
Developed markets - government related	379	-4	-4	-3	-16	-15	-11
Developed markets - corporates	1,064	-5	-4	-4	-56	-48	-47
Emerging markets	89	-3	-2	-3	-3	-2	-3
Total in local currency	**3,773**	**-4**	**-4**	**-3**	**-159**	**-158**	**-110**
Real Assets in local currency							
Listed real estate	216	-43	-27	-51	-93	-58	-110
Unlisted real estate	362	-22	-14	-26	-81	-51	-95
Unlisted infrastructure	14	-7	-5	-8	-1	-1	-1
Total in local currency	**592**	**-30**	**-19**	**-35**	**-175**	**-110**	**-206**
Total in local currency	**12,429**	**-30**	**-17**	**-40**	**-3,747**	**-2,152**	**-4,927**

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 real estate shows gross asset value for exposure and listed real estate only includes equity exposure. 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 2022.

	Billions of kroner	Shock			Impact		
		Percent			Billions of kroner		
	Market Value	De-anchored inflation exp.	Hard landing	Geo-political conflict	De-anchored inflation exp.	Hard landing	Geo-political conflict
Portfolio impact in local currency	12,429	-30	-17	-40	-3,747	-2,152	-4,927
Currency impact - developed markets	11,552	0	7	5	24	788	540
Currency impact - emerging markets	877	-1	6	3	-9	56	27
Portfolio impact in NOK	**12,429**	**-30**	**-11**	**-35**	**-3,732**	**-1,309**	**-4,361**

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 2022. 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	22
Asset positioning	22
Security selection	40
Internal security selection	39
External security selection	19
Fund allocation	124
Real estate	132
Unlisted real estate	69
Listed real estate	75
Environmental related mandates	3
Allocations	24
Total	**122**