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 2020 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

Charts 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.*
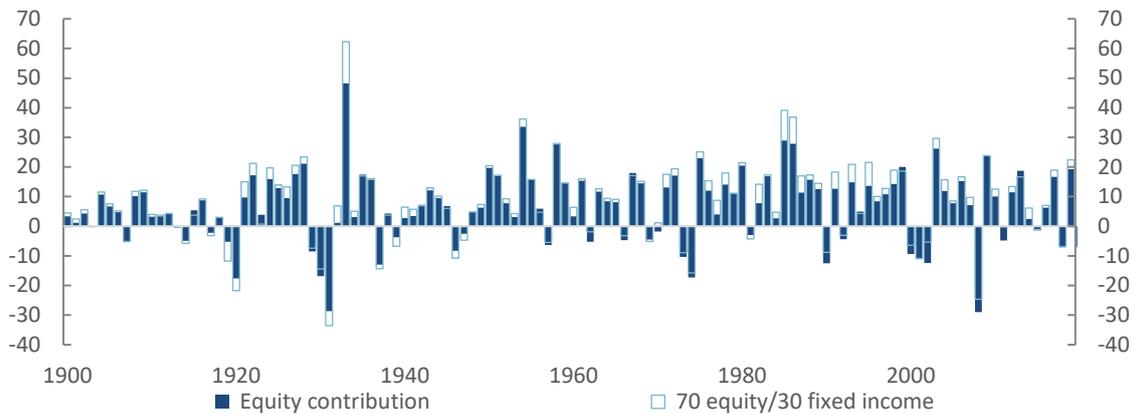
Source: Dimson-Marsh-Staunton global return data

Chart 2 *Annualised 3-year rolling return of 70 equity/30 fixed income. Measured in dollars. Percent.*
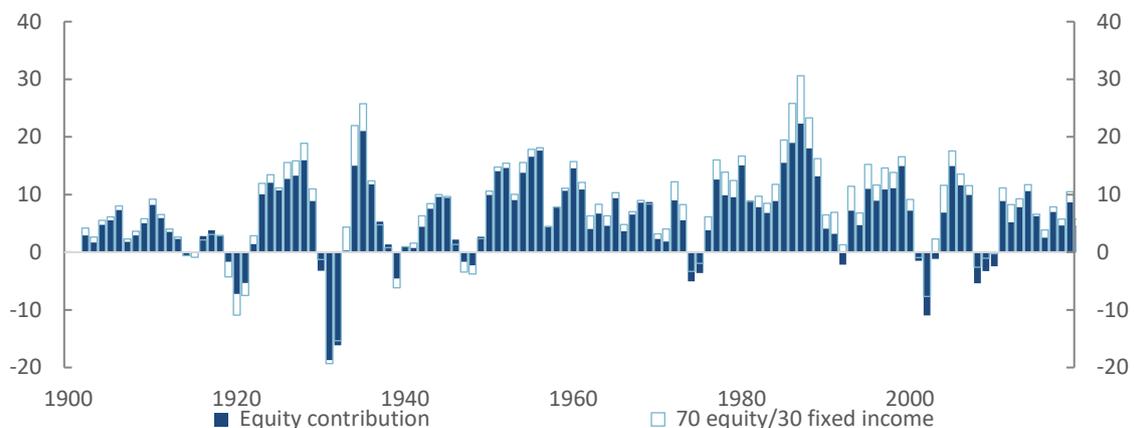
Source: Dimson-Marsh-Staunton global return data

Chart 3 *Annualised 5-year rolling return of 70 equity/30 fixed income. Measured in dollars. Percent.*
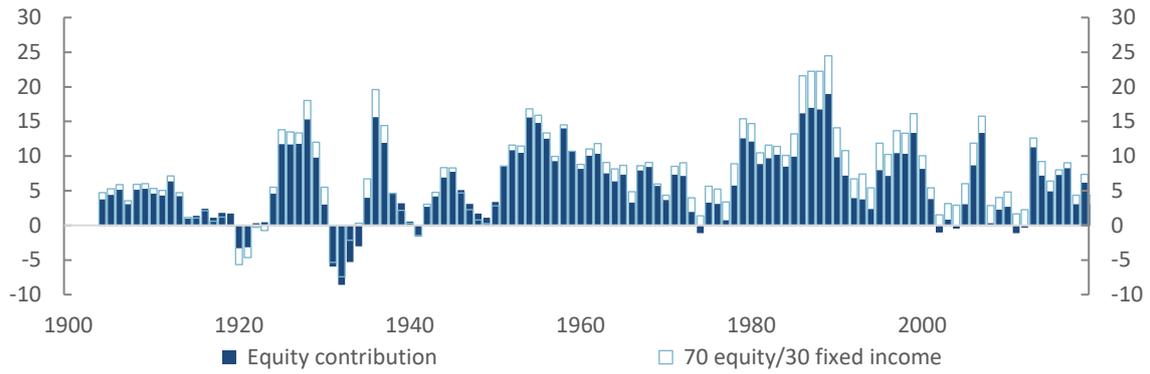
Source: Dimson-Marsh-Staunton global return data

Chart 4 *Annualised 10-year rolling return of 70 equity/30 fixed income. Measured in dollars. Percent.*
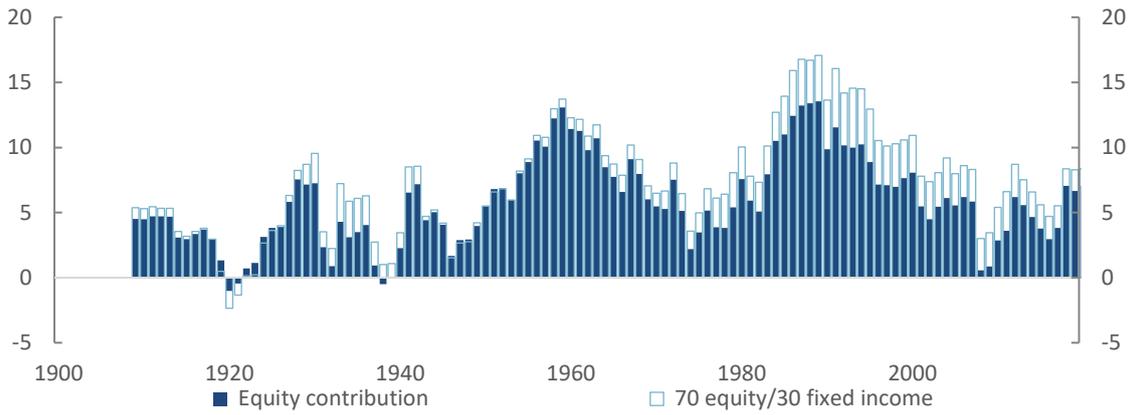
Source: Dimson-Marsh-Staunton global return data

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 2020, measured in the currency basket. Returns in percent of entity NAV.*

Event	First date	Last date	Numbers of months	Fund	Equity management	Fixed income management
Asian financial crisis	01.07.1997	31.12.1997	6	9.20%	10.83%	3.76%
Russian default	01.08.1998	30.09.1998	2	-8.04%	-12.35%	3.60%
Dot com crash 1	01.09.2000	31.03.2001	7	-8.21%	-12.85%	3.30%
9/11	01.09.2001	30.09.2001	1	-8.69%	-12.01%	0.28%
Dot com crash 2	01.01.2002	30.09.2002	9	-11.36%	-17.47%	4.84%
Global financial crisis	01.05.2008	28.02.2009	10	-31.12%	-40.77%	0.05%
Euro debt crisis	01.04.2011	30.11.2011	8	-4.69%	-8.32%	5.51%
Taper Tantrum	01.05.2013	31.08.2013	4	3.46%	6.53%	-5.08%
Oil price decline	01.07.2014	31.12.2014	6	5.83%	6.61%	3.08%
EM slowdown	01.06.2015	30.09.2015	4	-6.97%	-9.77%	-0.15%
Brexit referendum	01.06.2016	30.06.2016	1	-0.42%	-1.29%	2.18%
Volatility spike	01.09.2018	31.12.2018	4	-9.22%	-12.16%	-0.40%
Covid pandemic	01.02.2020	31.03.2020	2	-14.09%	-18.39%	-0.57%

Absolute expected shortfall

Charts 5 to 8 show the fund's expected shortfall for multiple tail probabilities using weekly historical simulations since January 2007. The charts also show 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 2020. Confidence level 90%. Percent.*
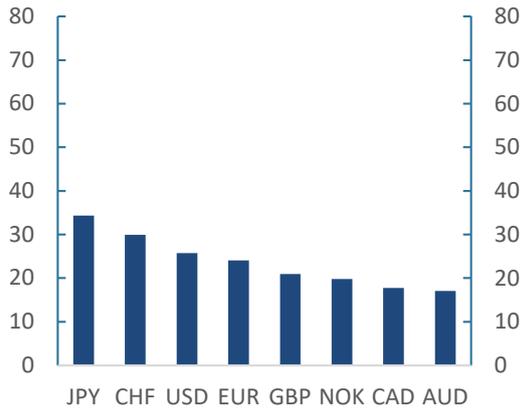
Chart 6 *Expected shortfall of actual portfolio as at 31 December 2020. Confidence level 95%. Percent.*
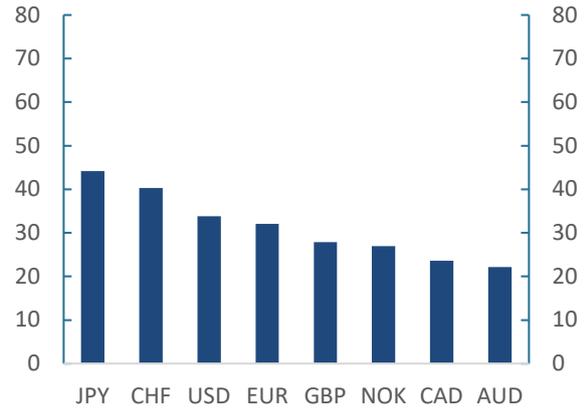
Chart 7 *Expected shortfall of actual portfolio as at 31 December 2020. Confidence level 97.5%. Percent.*
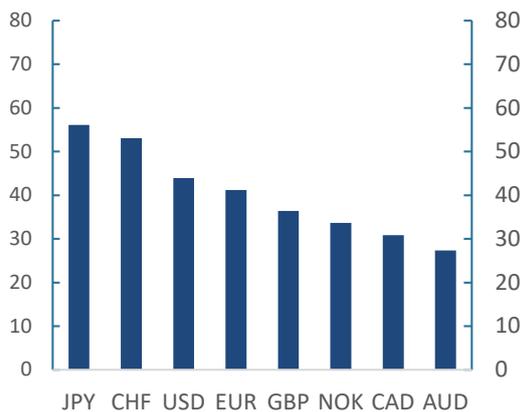
Chart 8 *Expected shortfall of actual portfolio as at 31 December 2020. Confidence level 99%. Percent.*
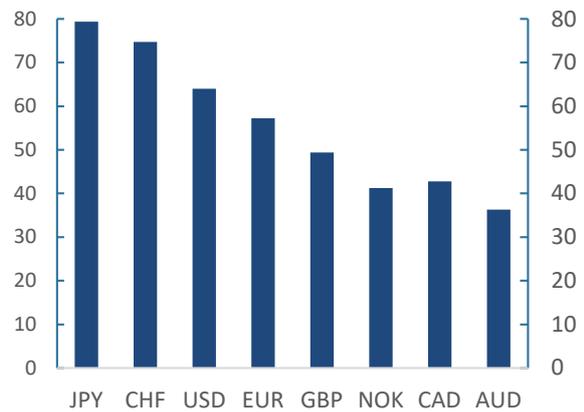
Hypothetical stress tests: Systematic risk factors

A drawback of historical simulations is that future crises may show different dynamics than stressed periods covered by the model. To investigate portfolio sensitivity to scenarios that are not perfect replications of historical events, Norges Bank Investment Management performs hypothetical stress tests. The three scenarios considered here are recessions associated with increases in uncertainty and decreases in risk appetite. They range from a mild scenario featuring flight-to-quality at one end, an extreme scenario featuring losses on all asset classes at the other end, and a medium scenario in-between. The GPFG portfolio exposures and shock impact for each risk factor are shown in table 2.

Table 2: Hypothetical recession scenario impact for GPFG portfolio as at 31 December 2020.

| | Exposure | | Shock | | | Impact | | |
| | Billions of Kroner Market value | Millions of Kroner DV01 | Prices in percent, rates in basis points | | | Billions of Kroner | | |
			Mild	Medium	Extreme	Mild	Medium	Extreme
Equities in local currency								
Developed markets- small cap	871		-15	-35	-55	-131	-305	-479
Developed markets- large cap	5,992		-15	-30	-50	-899	-1,798	-2,996
Emerging and Frontier markets	866		-20	-35	-55	-173	-303	-476
China A	84		-25	-35	-60	-21	-29	-50
Total in local currency	7,813					-1,224	-2,435	-4,002
Fixed income in local currency								
Developed markets- short term treasuries	416	53	-100	-50	100	5	3	-5
Developed markets- long term treasuries	1,112	1,223	-50	-50	100	64	64	-111
Developed markets- government related	310	184	-25	0	200	5	0	-32
Developed markets- corporates	858	557	25	50	500	-14	-27	-185
Emerging markets	144	84	175	200	450	-13	-15	-28
Total in local currency	2,839	2,101				47	25	-361
Real estate in local currency								
Listed	148		-15	-35	-55	-22	-52	-81
Unlisted	296		-5	-10	-25	-15	-30	-74
Total in local currency	443					-37	-81	-155
Total in local currency	10,914	2,101				-1,213	-2,491	-4,518
Foreign exchange								
Developed markets	10,046		15	0	-15	1,350	0	-897
Emerging markets	868		0	-15	-30	0	-88	-124
Total foreign exchange	10,914					1,350	-88	-1,021
Total NOK	10,914	2,101				136	-2,579	-5,539

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. Equity, real estate and foreign exchange price shocks are in percent. Fixed income interest rate shocks are in basis points.

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 3 shows relative expected shortfall for the fund as well as each of the fund's investment strategies.

Table 3: Expected shortfall relative to benchmark of investment strategies as at 31 December 2020. 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
Fund allocation	156
Reference portfolio	31
of which systematic factors	30
Real estate	132
Unlisted real estate	68
Listed real estate	77
Environmental related mandates	13
Allocations	15
Security selection	38
Internal security selection	37
External security selection	17
Asset management	25
Asset positioning	25
Total	180