STATE STREET GLOBAL MARKETS

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Which Currency Hedging Strategy is Best?

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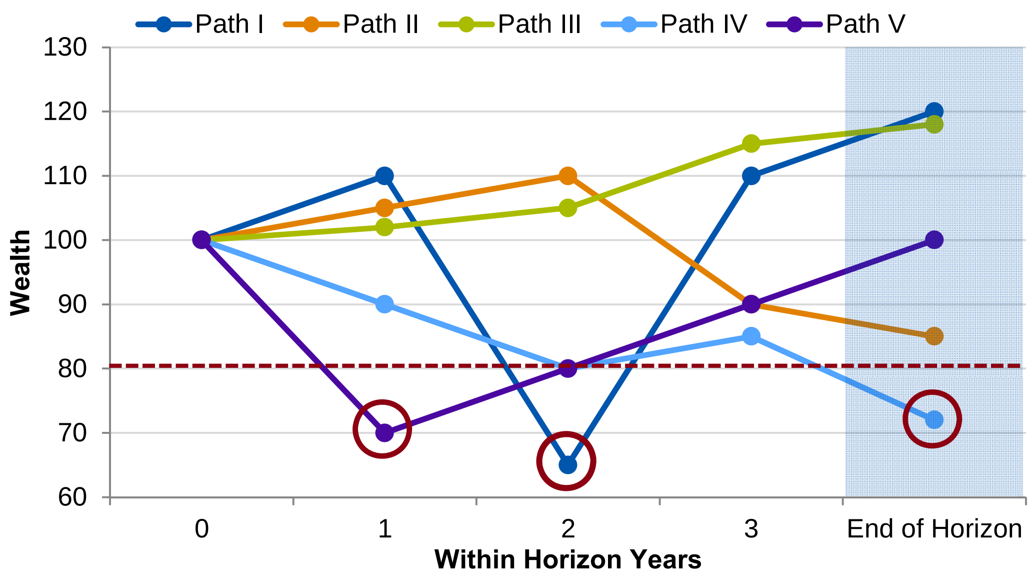
Outline

Why hedge?

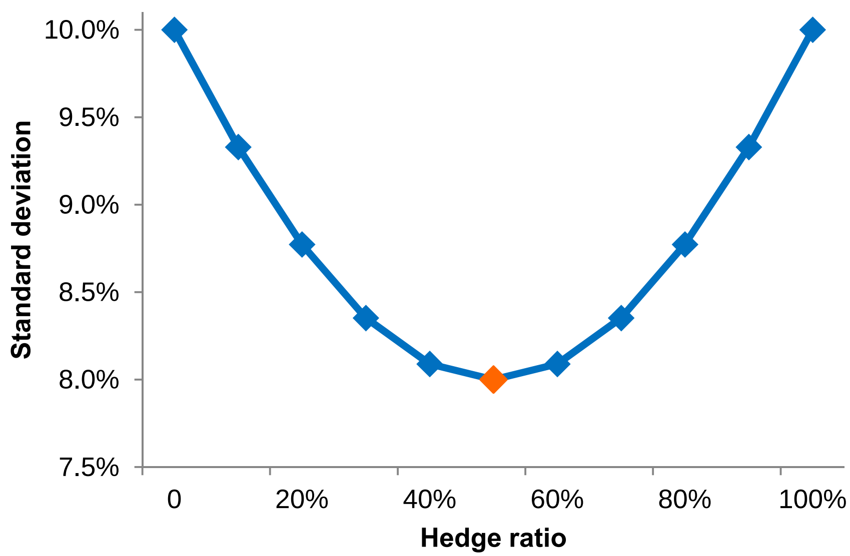
- Currencies contribute to within-horizon risk.
- Investors are not necessarily compensated for bearing currency risk.



Source: State Street Associates

Why not fully hedge?

- Currency exposure may introduce beneficial diversification.
- The optimal hedge ratio balances volatility and diversification to minimize total risk.



Note: Assume the portfolio has a 10% standard deviation. The only exposed currency has 12% standard deviation. The correlation between the portfolio and the currency is 60%. We find that the portfolio's volatility varies with the currency hedge ratio. A fully hedged scenario almost has the same risk as the unhedged portfolio.

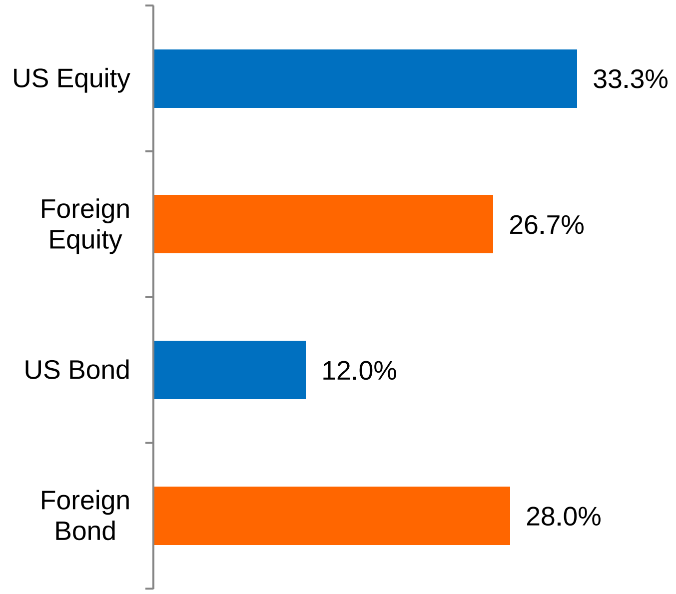
Source: State Street Associates

Linear hedging

- The objective is to minimize portfolio volatility.
- Using monthly return series from Feb 1998 to Mar 2013, we calculate the historical volatilities and correlations across all assets and currencies.

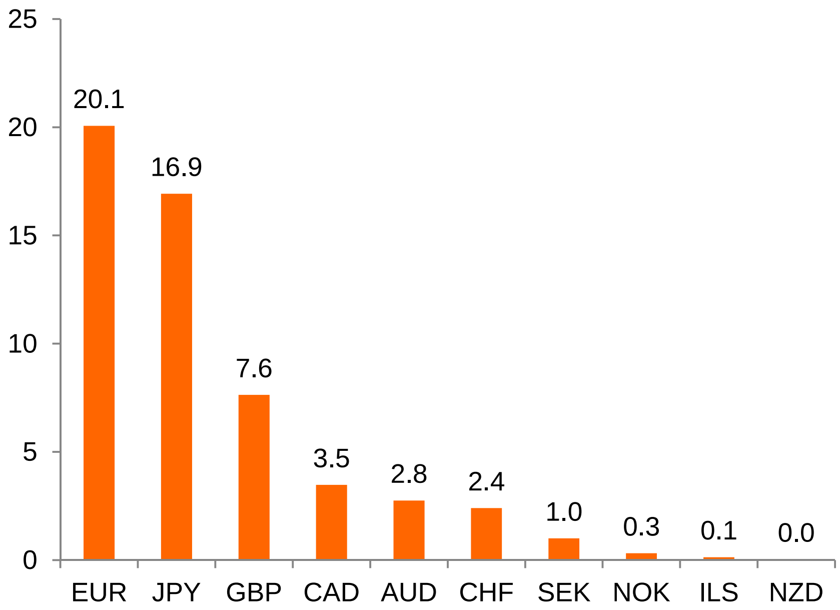
Illustrative portfolio

Portfolio Structure



Note: We assume a 60/40 allocation into equities and bonds. The country equity allocation is based on the MSCI DM Equity Index as of March 2013. The country bond allocation is based on the Citigroup Global Bond Index as of March 2013.

Currency Exposure (%)



Note: The chart shows the currency exposure as of March 2013. We use the Euro to proxy for the Danish kroner and the U.S. dollar to proxy for both the Singapore dollar and Hong Kong dollar, as these currencies are managed to be within fairly tight bands.

Source: State Street Associates

Correlations

- Correlations with the underlying portfolio vary by currency.

Correlation Matrix	Portfolio	AUD	CAD	CHF	EUR	GBP	ILS	JPY	NOK	NZD	SEK
Portfolio	1.00										
AUD	0.75	1.00									
CAD	0.66	0.71	1.00								
CHF	0.38	0.54	0.33	1.00							
EUR	0.56	0.67	0.46	0.86	1.00						
GBP	0.41	0.53	0.46	0.53	0.62	1.00					
ILS	0.43	0.41	0.43	0.32	0.38	0.29	1.00				
JPY	0.19	0.12	0.00	0.33	0.22	0.09	-0.10	1.00			
NOK	0.58	0.67	0.57	0.68	0.81	0.63	0.31	0.11	1.00		
NZD	0.65	0.84	0.55	0.60	0.66	0.51	0.33	0.14	0.58	1.00	
SEK	0.69	0.72	0.57	0.70	0.85	0.63	0.37	0.18	0.86	0.68	1.00

Based on monthly return data from Feb 1998 to Mar 2013.

Source: State Street Associates

Linear hedging constraints

	Fully-hedged	Optimal Currency-Specific	Allow Cross Hedging	Allow Over Hedging	Allow Asset Reallocation*
Asset weight	fixed	fixed	fixed	fixed	**variable**
Hedging Constraints	Each currency hedging amount = Portfolio's exposure to this currency	Each currency hedging amount <= Portfolio's exposure to this currency	Total currency hedging amount <= Portfolio's total currency exposure	Total currency hedging amount = 100%	Total currency hedging amount = 100%

*The portfolio return is constrained to be unchanged.

Source: State Street Associates

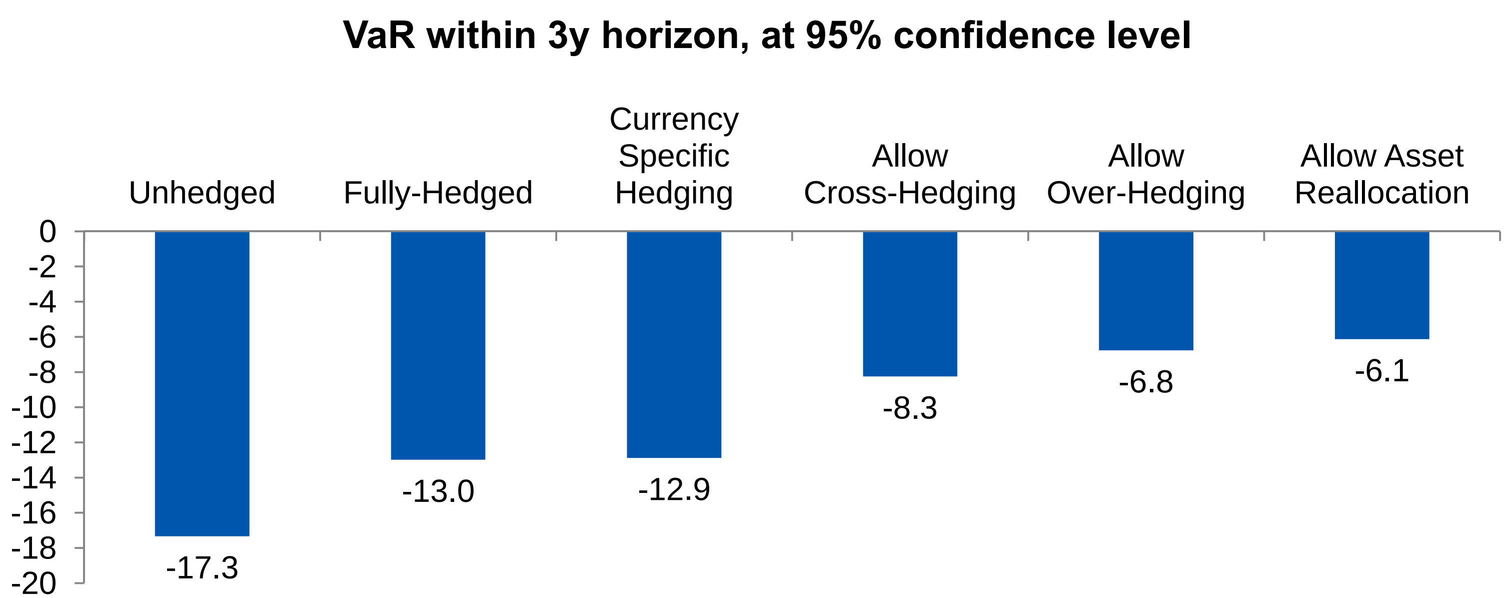
Linear hedging: Comparison of strategies

Currency exposure: 54.74%	Unhedged		Fully-hedged		Optimal Currency-Specific		Allow Cross Hedging		Allow Over Hedging		Allow Asset Reallocation*	
Currency Exposure	54.74		54.74		54.74		54.74		54.74		90.86**	
Hedge Positions	0		54.74		49.59		54.74		100		82.17	
	weight	ratio	weight	ratio	weight	ratio	weight	ratio	weight	ratio	weight	ratio***
AUD	0	0	(2.75)	1.0	(2.75)	1.0	(36.50)	13.3	(26.13)	9.5	(15.58)	3.5
CAD	0	0	(3.48)	1.0	(3.48)	1.0	(1.01)	0.3	(26.23)	7.5	(15.33)	2.7
CHF	0	0	(2.40)	1.0	(2.40)	1.0	0.00	0.0	0.00	0.0	0.00	0.0
EUR	0	0	(20.06)	1.0	(20.06)	1.0	0.00	0.0	0.00	0.0	(8.15)	0.2
GBP	0	0	(7.63)	1.0	(7.63)	1.0	0.00	0.0	0.00	0.0	0.00	0.0
ILS	0	0	(0.14)	1.0	(0.14)	1.0	(0.00)	0.0	(13.11)	96.4	(6.19)	28.8
JPY	0	0	(16.93)	1.0	(11.77)	0.7	0.00	0.0	(9.75)	0.6	(14.66)	0.5
NOK	0	0	(0.32)	1.0	(0.32)	1.0	0.00	0.0	0.00	0.0	0.00	0.0
NZD	0	0	(0.03)	1.0	(0.03)	1.0	(0.00)	0.0	(2.67)	84.9	(3.24)	65.2
SEK	0	0	(1.00)	1.0	(1.00)	1.0	(17.23)	17.2	(22.10)	22.0	(19.01)	11.8
Portfolio Volatility	**10.57%**		**8.76%**		**8.74%**		**6.88%**		**6.26%**		**5.96%**	

*We impose a tracking error constraint to ensure that the new portfolio composition would appear reasonable to a prudent investor. Tracking error aversion is 0.25.
**The assets are reallocated to 9.14% in US equity, 42.23% in foreign equity, 0% in US bond, and 48.63% in foreign bond. The total currency exposure is 90.86%. The tracking error of the portfolio is 3.40%.
**The ratio is based on the currency exposure of the reallocated portfolio.

Source: State Street Associates

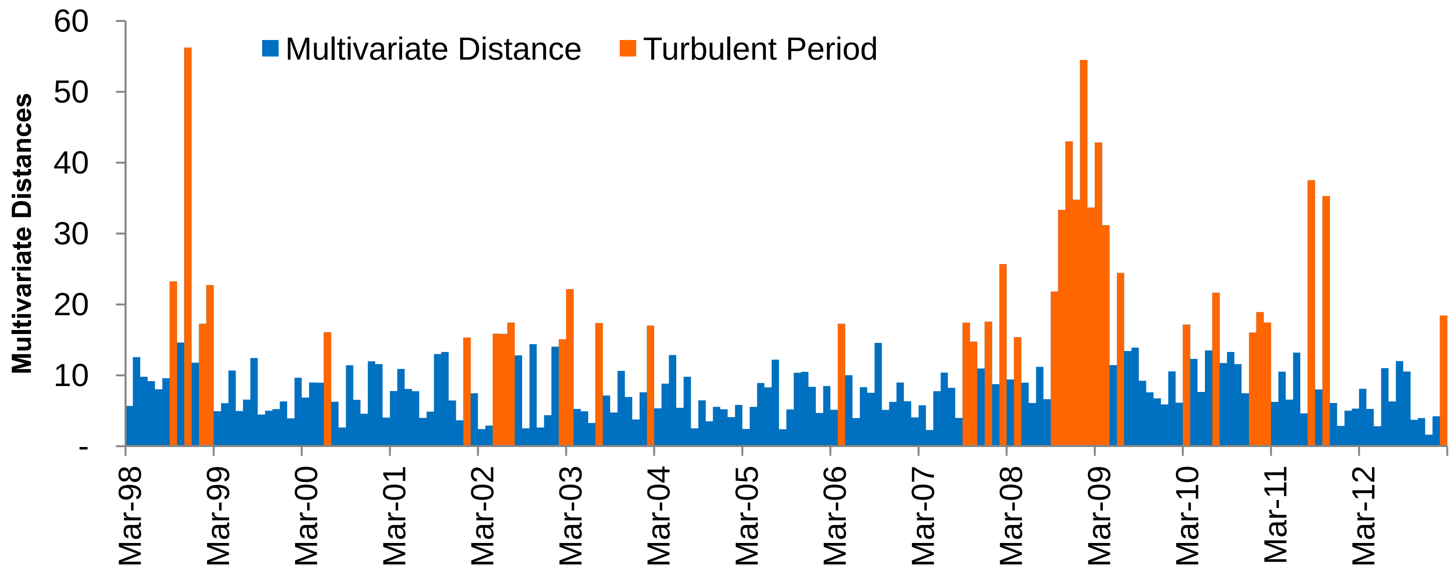
Risk regimes and stress tests



Source: State Street Associates

Risk regimes and stress tests: Financial turbulence

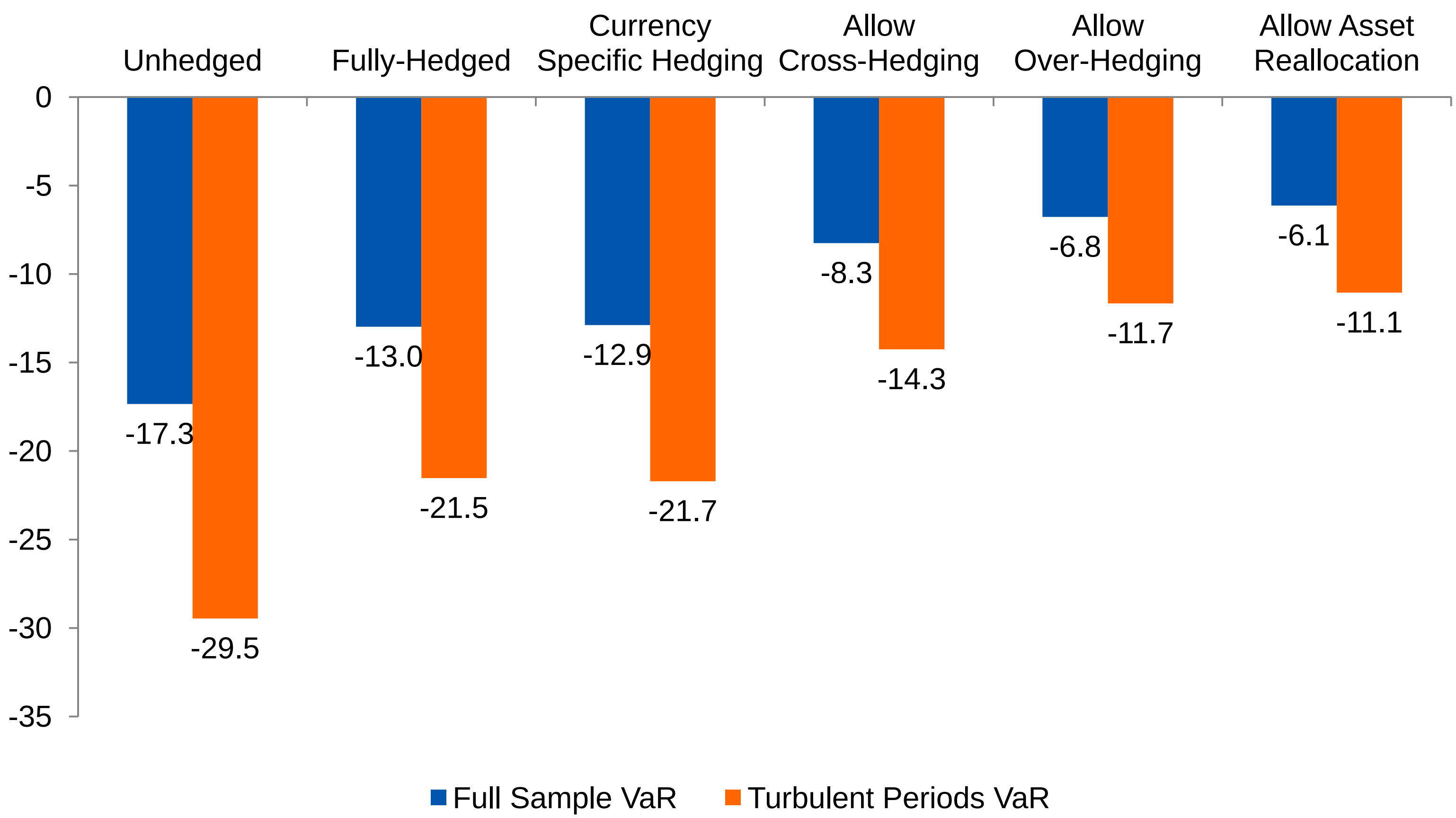
- We define financial turbulence as a condition in which asset prices behave in an uncharacteristic fashion, given their historical pattern of behavior.
  - Extreme price moves
  - Decoupling of correlated assets
  - Convergence of uncorrelated assets



* The multivariate distances are calculated based on the monthly returns of the portfolio and its currency exposures from Jan 1998 to Jan 2013. We define the turbulent periods as the 20% largest multivariate distances.

Source: State Street Associates

VaR within a 3 year horizon (95% confidence)



Source: State Street Associates

Non-linear hedging

- Linear hedging eliminates both the upside and downside of currency exposure.
- Non-linear hedging has potential to reduce downside while preserving some upside.
- Dynamic hedging and the use of options are examples of non-linear strategies.

Non-linear hedging

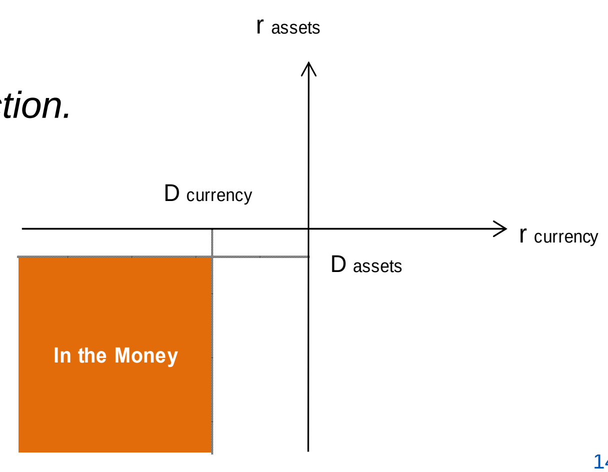
- We consider a range of potential non-linear strategies:

  1. **Individual options**
     - *Buy multiple put options, one for each currency exposure.*
     - *Provides the most protection.*

  2. **Basket option**
     - *One option to cover all currency exposures.*
     - *Cheaper than individual options due to correlations among currencies.*

  3. **Contingent option on foreign asset & currency**
     - *Protects against simultaneous losses from both foreign assets and currencies.*
     - *Cheaper than the basket option because it provides less protection.*

  4. **Contingent option on total asset & currency**



Source: State Street Associates

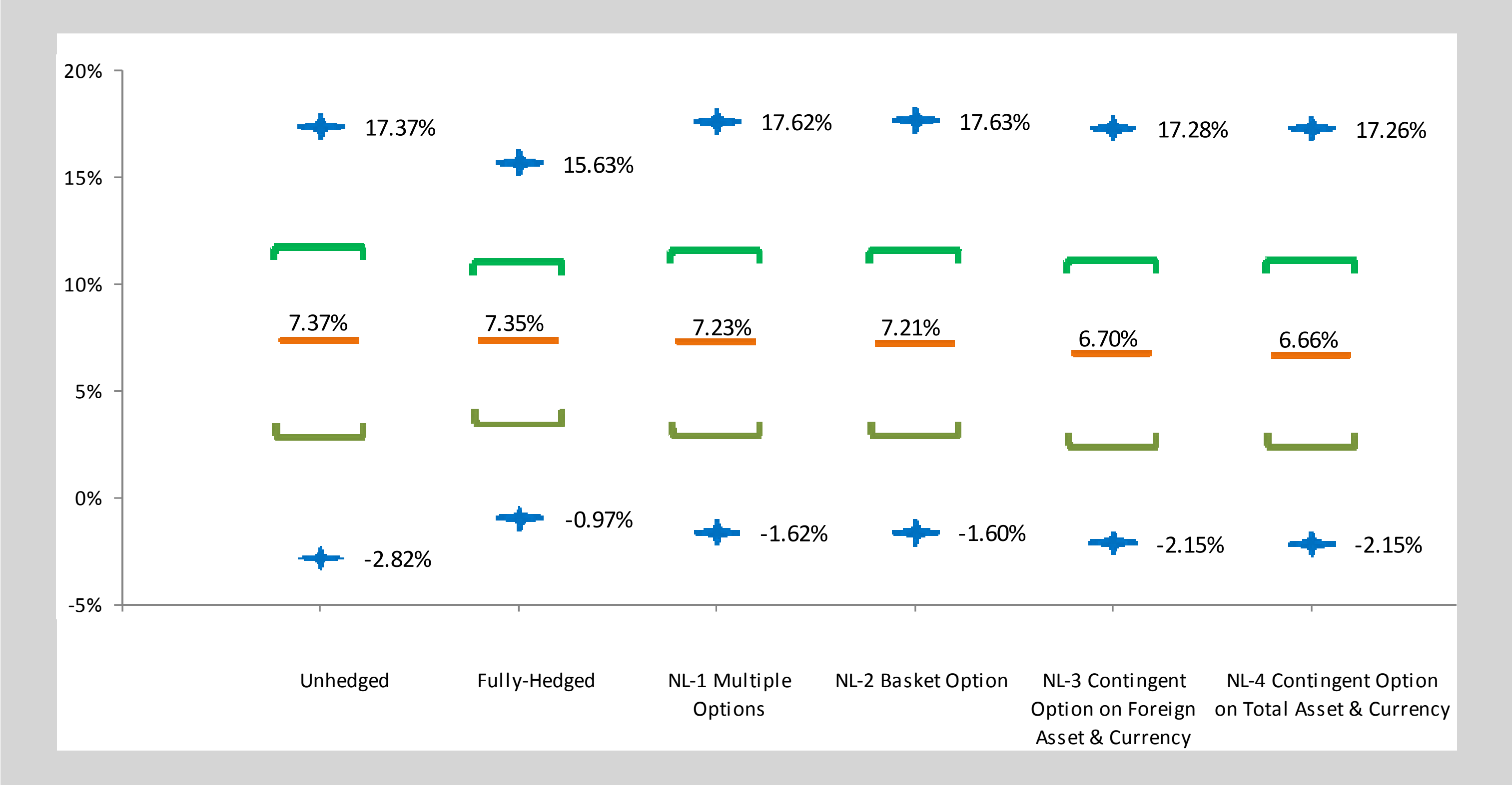
Non-linear hedging: Assumptions

- We use simulation to generate option prices.

- We assume:
  - The options are quarterly at-the-money European put options
  - The underlying assets are the currency exposures whose prices follow a Geometric Brownian motion based on historical volatilities and correlations

Non-linear hedging: Full sample return distribution

- Compared to a fully hedged scenario, non-linear hedging protects the downside while preserving some of the upside.

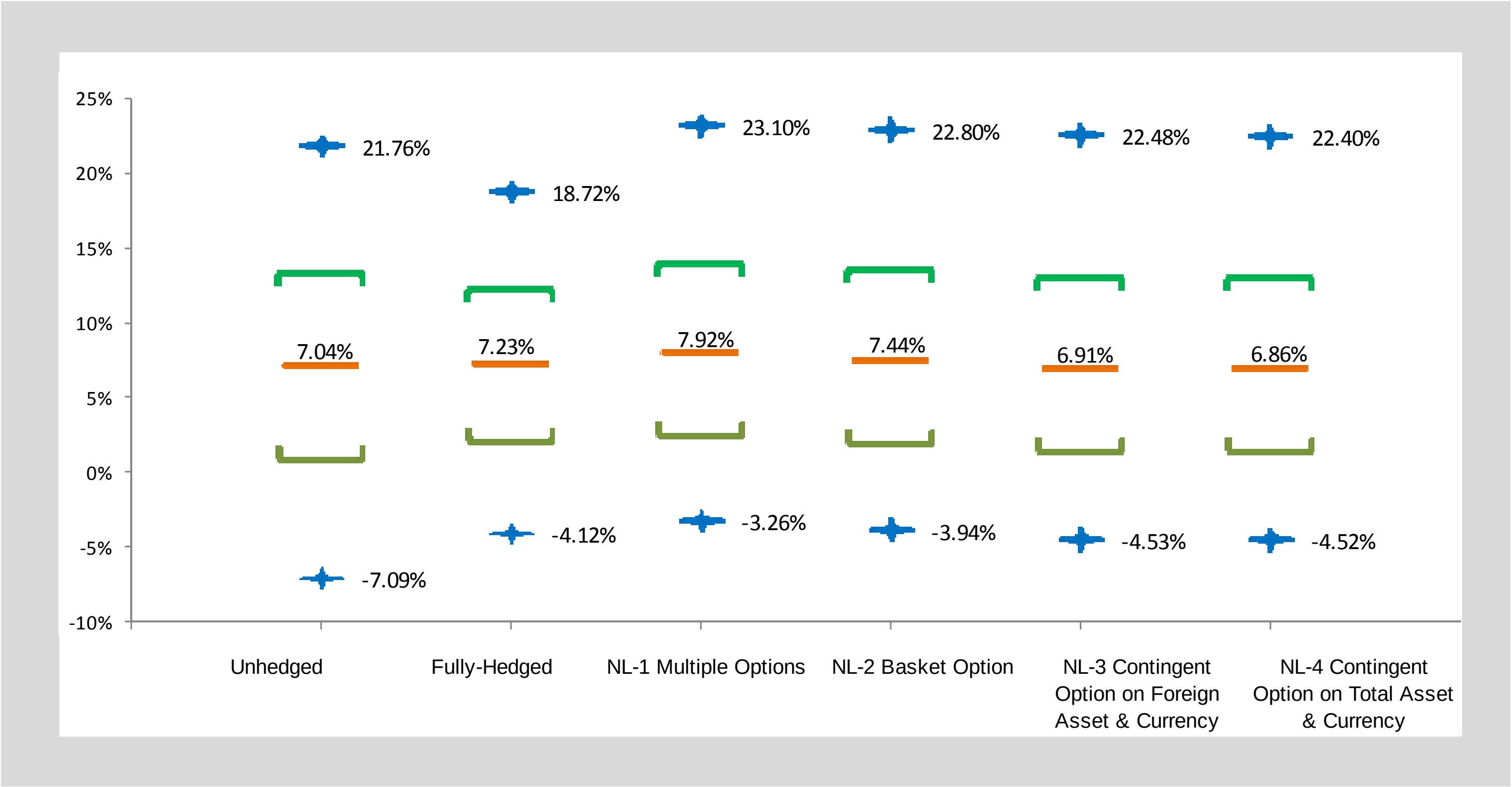


* Return distribution is calculated via Monte-Carlo simulation.

Source: State Street Associates

Non-linear hedging: Return distribution assuming turbulence

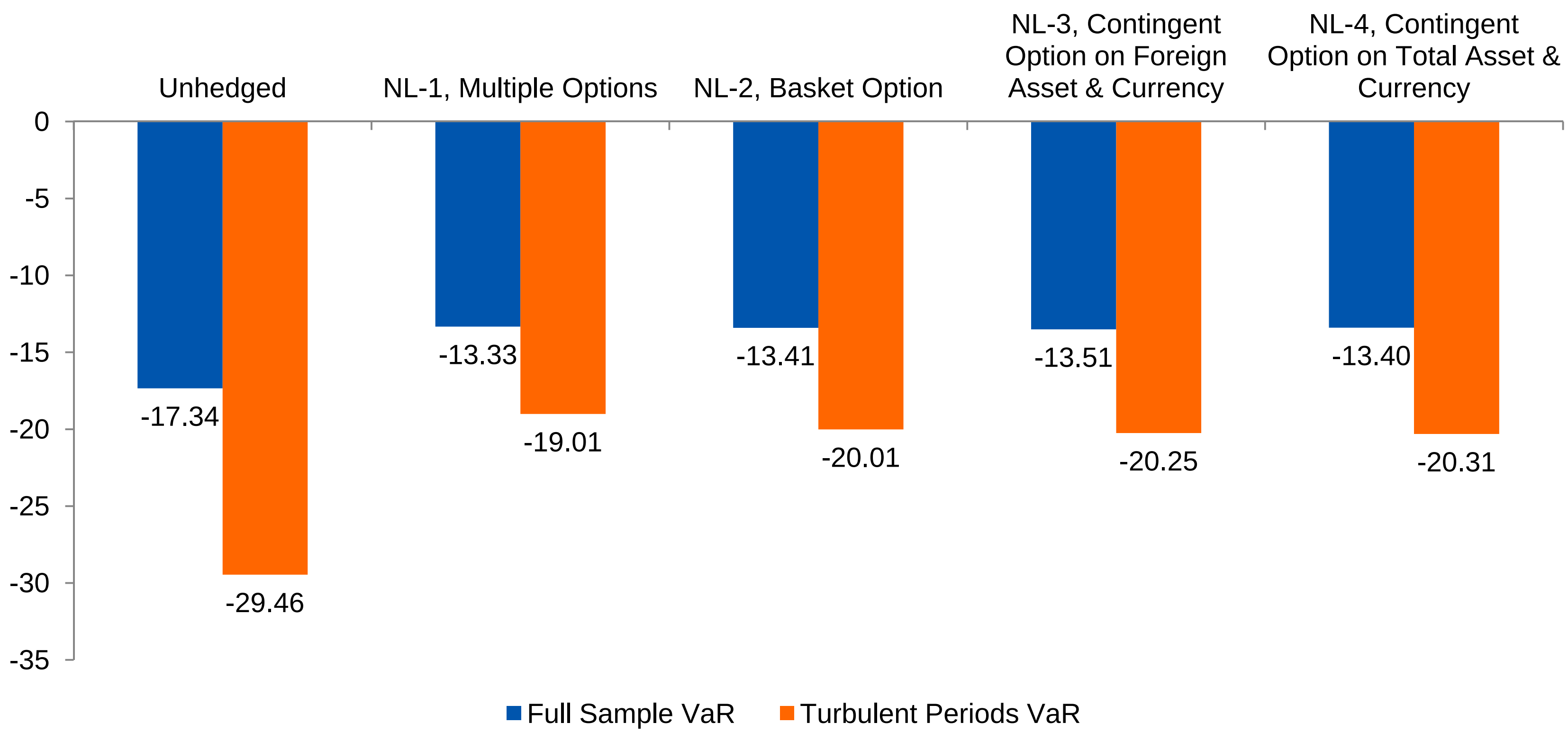
- Downside protection is more obvious during turbulent periods.



* Return distribution is calculated via Monte-Carlo simulation.

Source: State Street Associates

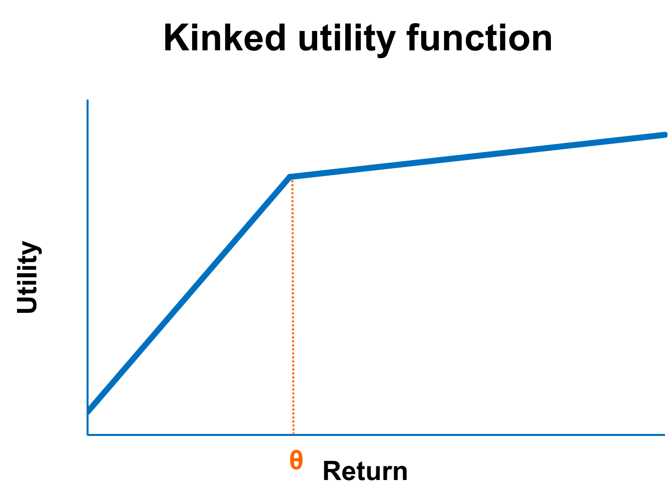
VaR within a 3 year horizon (95% confidence)



Source: State Street Associates

Combining linear and non-linear hedging

- Full-scale optimization maximizes utility based on the full empirical distribution of asset returns.



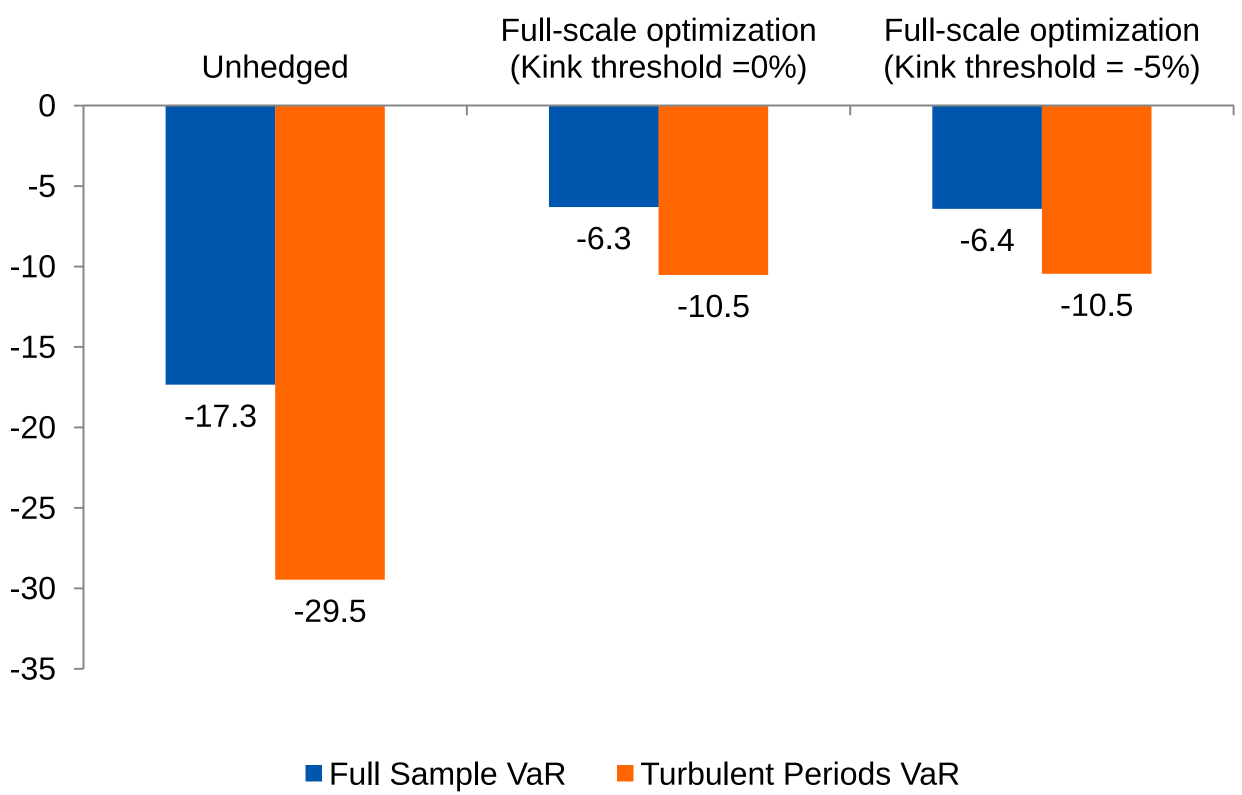
Source: State Street Associates

Combining linear and non-linear hedging: Results

	Kink Threshold = 0%		Kink Threshold = -5%	
Forwards	weight	ratio	weight	ratio
AUD	**-26.11**	9.5	**-27.98**	10.2
CAD	**-27.09**	7.8	**-27.49**	7.9
CHF	0.00	0.0	0.00	0.0
EUR	0.00	0.0	0.00	0.0
GBP	0.00	0.0	0.00	0.0
ILS	**-13.26**	97.5	**-14.27**	104.9
JPY	**-8.42**	0.5	**-6.08**	0.4
NOK	0.00	0.0	0.00	0.0
NZD	**-3.25**	103.5	**-1.34**	42.7
SEK	**-21.86**	21.8	**-22.27**	22.2
Put options				
AUD	0.00	0.0	0.00	0.0
CAD	0.00	0.0	**6.53**	1.9
CHF	0.00	0.0	0.00	0.0
EUR	0.00	0.0	0.00	0.0
GBP	0.00	0.0	0.00	0.0
ILS	0.00	0.0	**0.26**	1.9
JPY	**1.92**	0.1	**6.64**	0.4
NOK	0.00	0.0	0.00	0.0
NZD	0.00	0.0	**0.03**	0.9
SEK	0.00	0.0	0.00	0.0

Source: State Street Associates

VaR within a 3 year horizon (95% confidence)



Source: State Street Associates

Summary: Strategy tradeoffs

- Investors who have limited access to sophisticated hedging products (such as options) and who seek to minimize total portfolio volatility would more likely consider linear hedging strategies.
- Relaxing the constraints applied to linear strategies allows for greater risk reduction, but often at the expense of upside gains.
- Investors who aim to protect the downside of their portfolios while maintaining upside potential may likely consider the usage of options.
- In deciding which option structure to use, investors should consider the tradeoffs associated with the option premiums and amount of protection provided.
- Investors who can engage in both linear and non-linear hedging may consider using full-scale optimization to determine the optimal policy combining currency forwards and options.

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