Risk Decomposition under Parameter Uncertainty & Price Movement

MAKE LATENT RISKS AND UNSTABLE HEDGES VISIBLE

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Two Slide Overview (1/2)

1. **Risk Decomposition** is a tool to understand portfolio's net risk
2. **Net risk** = what remains after hedges cancel
   For example, in market neutral, longs – shorts = hedged market effect of 0 + other risks
3. **Hedged risks** are **often bigger** (before canceling out) **than the net**
   Imagine the amount of market effect in each side of long/short
4. **Numbers are inexact**
   → **'hedged' risks**, which can be large, **actually aren't and contribute to the net**

Two Slide Overview (2/2)

5. **How can numbers be off? Two ways**
   Parameter uncertainty from estimation error

   Dynamic portfolio composition over the horizon of interest
   Price movement alters position weights
   Hedges hold for an instant, fluctuate as weights shift

6. **What do you do?**
   Regard everything as uncertain
   Work from estimates of mean and variance instead of fixed values
      For parameters – center and error generated during inference
      For weights – distribution of future portfolio weights over horizon

7. **Risk decomposition** reports **expected value ± standard deviation**
   Surface latent fragility

Conceptual Presentation, No Math

See papers for math

Risk decomposition with uncertainty

- Section V of *Shah, A. (2019). Uncertain risk parity.* http://ssrn.com/abstract=3406321

With uncertainty and price movement

- *Shah, A. (2021). Uncertain and dynamic risk contributions.* <coming>

Criticism and questions: AnishRS@InvestmentGradeModeling.com

Risk Decomposition

Breaks portfolio's volatility (in variance or std dev) into sources

S&P500 volatility by factors		
Factor	**Exposure**	**Risk contribution**
Beta	0.95	16.32
Mkt Cap	2.53	2.10
Price Volatility	-0.84	1.04
Relative Strength	0.39	0.49
Book/Price	-0.50	0.38
⋮		
Earnings Variability	0.09	-0.05
		20.73

S&P500 volatility by sector buckets		
Sector	**Wt**	**Risk contribution**
Information Technology	32.4	7.62
Consumer Discretionary	14.0	3.23
Health Care	15.0	2.87
Financials	9.7	1.98
Consumer Staples	8.0	1.53
⋮		
Communication Services	2.3	0.29
	100	**20.73**

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Risk Contributions Geometrically

Menchero and Davis(2011). Risk contribution is exposure times volatility times correlation

Risks = directions (like north-south, east-west)

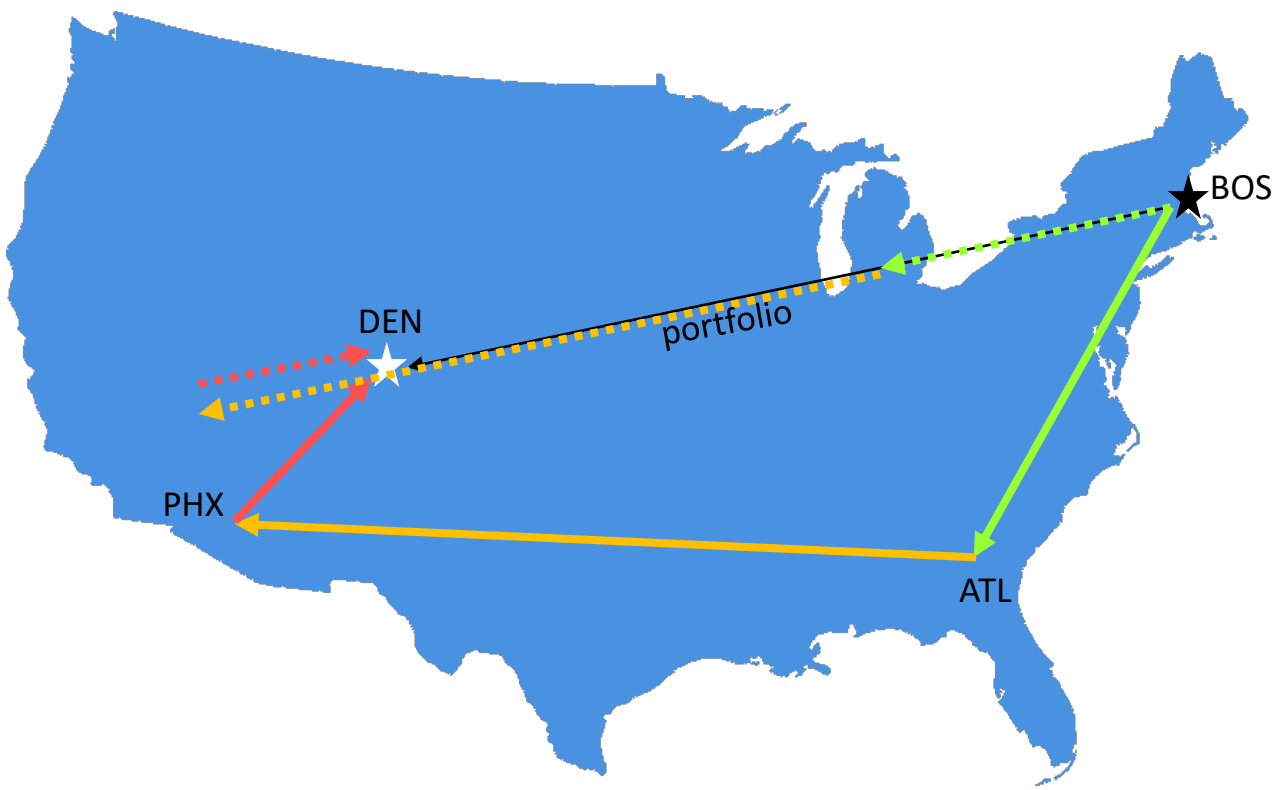
An investment (travel leg here) is a weighted combination of risks

Standard deviation = length

A portfolio is a sum of investments

Std dev contribution = length in the direction of the portfolio

All the movement in other directions nets out to zero



How can this go wrong?

Risk contributions are calculated from

- **Covariance between securities** ← estimated with error
- **Portfolio weights** ← fluctuate with prices

Ingredients are inexact

- **Risks that appear neutralized aren't** to some degree

Moreover, the **conventional view considers only the net**

- The magnitude of components involved doesn't matter

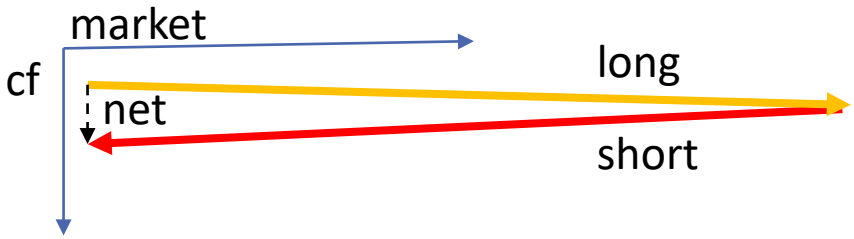
e.g., Long beta=1 stock, short another beta=1 and
Long beta=3 stock, short another beta=3 **appear the same**

- In reality, the second has much more **error and instability, contains large hidden risks**

How Things Go Wrong in Pictures

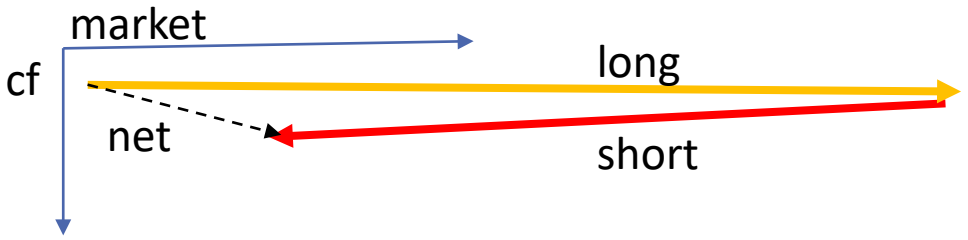
Imagine two directions of risk – market and chicken feed – and investing long-short

Beta hedged → net risk only in chicken feed → no market in risk contributions



What if perception is off and beta isn't hedged?

- The large market component in each side, mismatched, drives the risk of the net



Perceived-as-hedged directions vanish regardless of sensitivity to underlying offsetting risks

- Imagine looking at the equity of a levered company without separately seeing the debt
- Hidden unstable risks at both the individual investment and portfolio levels

Optimization finds perceived hedges

Another Hitch – Price Movement

Stability of hedges – hedged today doesn't mean hedged tomorrow

Stylized example on two beta=1 portfolios:

Portfolio A – 50% beta=1 stock + 50% another beta=1 stock

- Portfolio maintains beta=1 regardless of price changes

Portfolio B – 50% cash + 50% beta=2 stock

- Market rises 10%. Portfolio is 45% cash, 55% stock, has beta=1.1
- Market falls 10%. Portfolio is 55% cash, 45% stock, has beta=0.9
- **Beta exposure is constantly changing, unstable**

Can quantify stability by assessing risk across the future distribution of portfolio weights

What do you do?

Problems

- Parameter estimates are unavoidably imperfect
- Portfolio composition changes with price movement

Solution

- **Evaluate across the range of what's possible**
- Use parameters' mean **and covariance**
- **Model** distribution of **portfolio weights over the horizon** of interest
- **± range accompanies numbers in risk decomposition**

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SP500 Factor Risk Decomposition with Uncertainty but no Price Movement

	Exposure	±	Conventional Risk	Uncertain Risk	±
Total			20.73	26.01	5.20
Beta	0.95	0.01	16.32	13.03	3.35
Mkt Cap	2.53	0.01	2.10	8.18	6.08
Price Volatility	-0.84	0.12	1.04	2.43	2.45
Relative Strength	0.39	0.10	0.49	1.00	1.21
Book/Price	-0.50	0.03	0.38	0.47	0.61
Trading Activity	-0.26	0.06	0.13	0.31	0.42
⋮					
Stock Specific			0.24	0.18	0.04

Note: uncertainty occurs in both exposures and factor/stock-specific variance levels

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SP500 Sector Risk Decomposition with Uncertainty but no Price Movement

	Weight	Conventional Risk	Uncertain Risk	±
Total	100	20.73	26.01	5.20
Information Technology	32.4	7.62	10.05	2.27
Consumer Discretionary	14.0	3.23	3.99	0.84
Health Care	15.0	2.87	3.85	1.00
Financials	9.7	1.98	2.12	0.36
Consumer Staples	8.0	1.53	1.65	0.25
Industrials	7.3	1.17	1.71	0.51
Energy	2.9	0.68	0.61	0.19
⋮				

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Example of Risk Decomposition with Uncertainty and Price Movement

Minimum variance long/short: 100% long, 100% short, 22 stocks – 1 in each sector on each side

		Total	AWK	TMUS	CLX	SBAC	ODFL	COG	MKTX	AMZN	NEM	…
Weight		100	20.0	18.2	15.3	14.6	10.5	9.8	6.4	1.8	1.3	
Conventional	Risk	19.5	1.64	1.60	1.35	1.29	0.93	0.87	0.57	0.16	0.12	
5 day price movement	Risk	19.6	1.62	1.59	1.34	1.28	0.91	0.86	0.56	0.16	0.12	
	±	1.9	0.17	0.15	0.11	0.19	0.13	0.17	0.09	0.02	0.01	
Parameter uncertainty	Risk	23.0	1.98	1.81	1.65	1.58	1.25	0.79	0.70	0.20	0.16	
	±	4.0	0.64	0.62	0.57	0.70	0.57	0.43	0.35	0.09	0.08	
Both	Risk	23.2	1.96	1.79	1.63	1.56	1.24	0.77	0.69	0.20	0.16	
	±	4.7	0.72	0.69	0.61	0.78	0.63	0.53	0.38	0.09	0.08	

Summary

Risk decomposition is a canonical, useful tool to assess a portfolio's risks

But **perfect alignments** (as arise from optimization) **hide risks**
… and **ingredients are uncertain**, so such alignments don't really exist
… and **price movement breaks them** even if they did

The solution is to **analyze with parameters and weights explicitly modeled as uncertain**

Surfaces latent risks and fragility

Coming to Northfield!

For more on modeling uncertainty: Shah A. 'Uncertain Covariance Models & Uncertainty-Penalized Portfolio Optimization.' Northfield 2018 annual conference

Something to chew on – for more stability, how about optimizing a portfolio's future variance?