SOURCES OF MARKET RISK

DECOMPOSITION

Losses can occur because of a combination of two factors:

- The exposure to the factor (a choice variable)
- The movement in the factor itself (which is external to the portfolio)

Example: Fixed-coupon bond

The potential for loss can be decomposed into the effect of dollar *duration* D^*P and the changes in the yield dy

$$dy / dp = -(D^*P) \quad \rightarrow \quad dy = -(D^*P) \times dy \qquad (11.1)$$

- It is possible to decompose the return on stock *i* into a market component and some residual risk

$$R_i = \alpha_i + \beta_i \times R_M + \varepsilon_i \approx \beta_i \times R_M \qquad (11.2)$$

α_i is a constant: does not contribute to risk

ε_i specific risk that can be diversified

DECOMPOSITION

- R_i is the **rate of return** ➔ no dimension

  To get a change in a dollar price, we write

$$dP_i = \quad R_i P_i \approx \quad \beta_i \times P_i \times R_M \qquad (11.3)$$

- Similarly, the change in the value of a derivative *f* can be expressed in terms of the change in the price of the underlying asset *S*,

$$df / dS = \Delta \quad \rightarrow \quad df = \Delta \times dS \qquad (11.4)$$

- Notation: Δ is the first partial derivative of the option
- *df* and *dS* are changes expressed in infinitesimal amounts

- The change in value is linked to an **exposure** coefficient and a change in market variable:

  Market loss = Exposure × Adverse movement in financial variable

RISK

- First Moment: price movements ➔ S_t = \$100, S_{t+1} = \$96
  ➔ Returns: $R_t = \ln(S_{t+1} / S_t)$
- Second Moment: Volatility ➔ Remember: usually we look at the volatility of the return process (not price)
- Cross Movements: Correlations ➔ Remember: usually we look at the correlation of returns (not prices)

CURRENCY RISK: PRICE MOVEMENTS

Currency risk arises in the following environments

- **Pure currency float**: the external value of a currency is free to move, to depreciate or appreciate ➔ market forces: example dollar/euro FX

- **Fixed currency system**: a currency's external value is fixed (or pegged) to another currency: example is the Hong Kong dollar, which is fixed against the U.S. dollar ➔ This does not mean there is no risk: possible readjustments in the parity value ➔ devaluations or revaluations

- **Change in currency regime**: a currency that was previously fixed becomes

  flexible, or vice versa: example the Argentinian peso was fixed against the

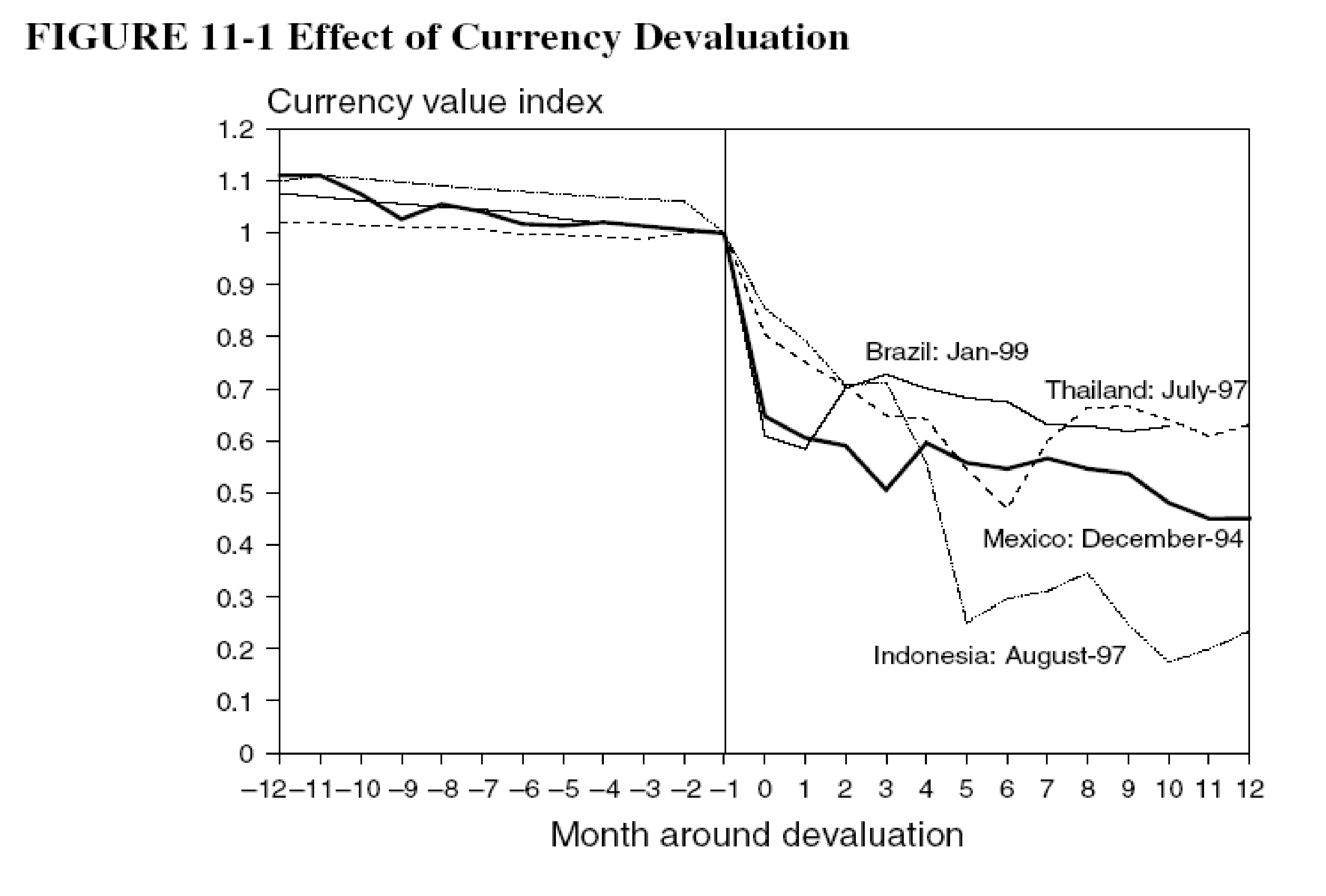
  dollar until 2001 and floated thereafter ➔ Changes in regime can also lower currency risk, as in the recent case of the euro.

CURRENCY RISK: VOLATILITY

TABLE 11.1 Currency Volatility against U.S. Dollar (Percent)

Country	Currency Code	End 2006 Daily	End 2006 Monthly	End 2006 Annual	End 1996 Annual
Argentina	ARS	0.269	1.073	3.72	0.42
Australia	AUD	0.374	1.995	6.91	8.50
Canada	CAD	0.338	1.840	6.37	3.60
Switzerland	CHF	0.403	2.223	7.70	10.16
Denmark	DKK	0.361	1.933	6.70	7.78
Britain	GBP	0.383	2.072	7.18	9.14
Hong Kong	HKD	0.035	0.161	0.56	0.26
Indonesia	IDR	0.286	1.443	5.00	1.61
Japan	JPY	0.363	2.040	7.07	6.63
Korea	KRW	0.325	1.675	5.80	4.49
Mexico	MXN	0.324	1.856	6.43	6.94
Malaysia	MYR	0.311	1.430	4.95	1.60
Norway	NOK	0.520	2.760	9.56	7.60
New Zealand	NZD	0.455	2.642	9.15	7.89
Philippines	PHP	0.197	1.087	3.76	0.57
Sweden	SEK	0.498	2.535	8.78	6.38
Singapore	SGD	0.183	0.991	3.43	1.79
Thailand	THB	0.645	2.647	9.17	1.23
Taiwan	TWD	0.217	1.093	3.79	0.94
South Africa	ZAR	0.666	4.064	14.08	8.37
Euro	EUR	0.360	1.934	6.70	8.26

CURRENCY RISK: VOLATILITY



CURRENCY RISK: CORRELATION

- Currency risk is also related to interest rate risk

  Often, interest rates are raised in an effort to stem the depreciation of a currency ➔ positive correlation between the currency and the bond market

- Generally, correlations are low: -0.10 to 0.20 ➔ Diversification

- Some correlations are high: currencies in the Euro area

- Triangular Arbitrage: example S_1 represents the dollar/pound rate and that S_2 represents the dollar/euro (EUR) rate ➔ S_3(EUR/BP) = S_1($/BP)/$S_2$($/EUR)

- In Logs: $\ln[S_3] = \ln[S_1] - \ln[S_2]$ (11.6)

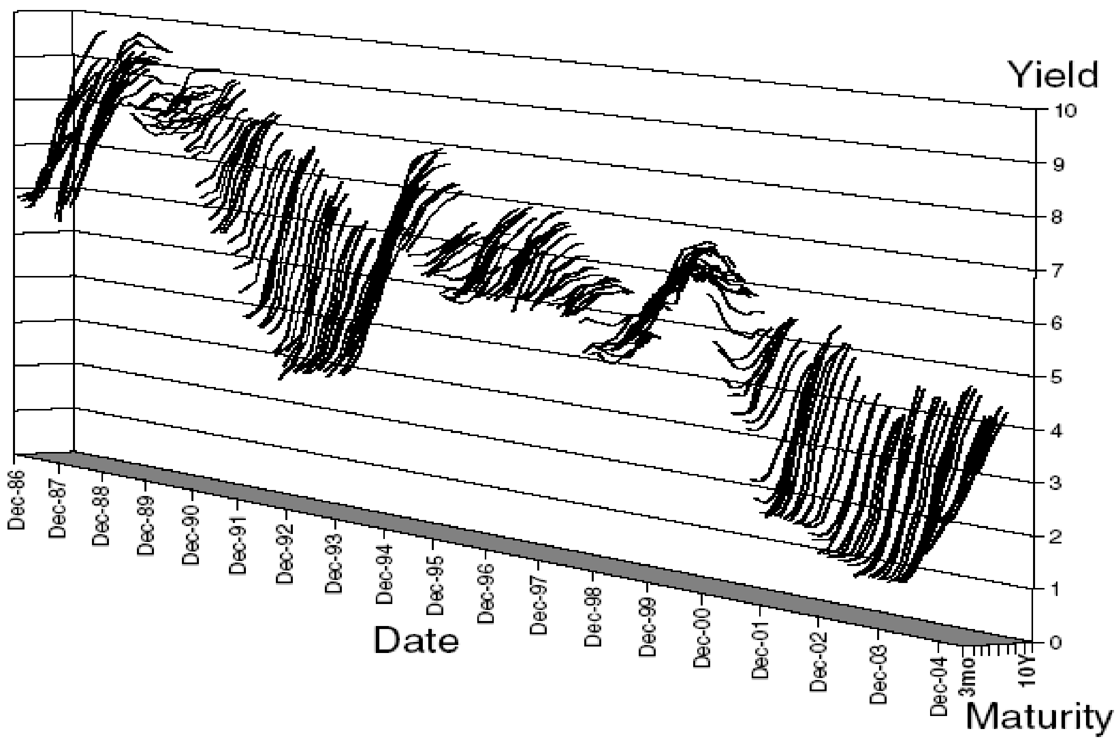
- Volatility:

$$\sigma_3^2 = \sigma_1^2 + \sigma_2^2 - 2\rho_{12}\sigma_1\sigma_2 \qquad (11.7)$$

FIXED INCOME RISK

- Fixed-income risk arises from movements in the level and volatility of bond yields → yield curve risk

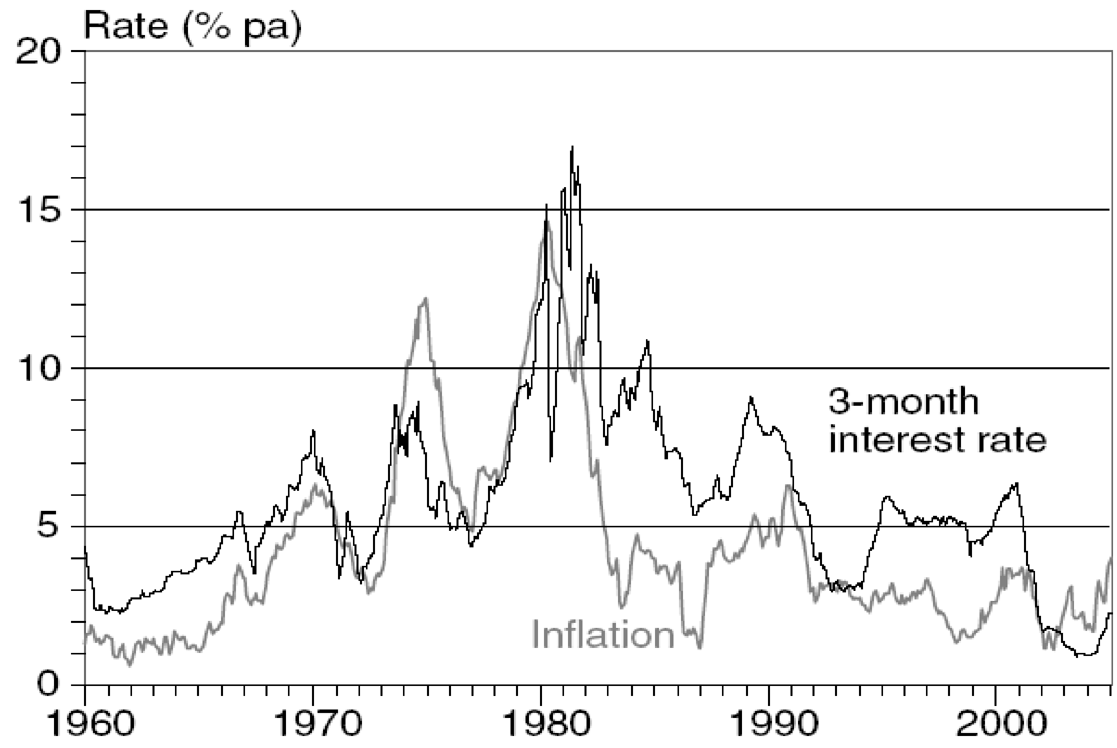
FIGURE 11-2 Movements in the U.S. Yield Curve



FIXED INCOME RISK

- Yields move because economic fundamentals are moving: Inflationary expectations

FIGURE 11-3 Inflation and Interest Rates



FIXED INCOME RISK

- The real interest rate is often defined as the nominal rate minus the rate of inflation ➔ $r_{r,t} = r_{n,t} - \pi_t$ ➔ $(1 + r_{r,t}) = (1 + r_{n,t})/(1 + \pi_t)$

  This is generally positive but in recent years has been negative ➔ the Federal Reserve has kept nominal rates very low to stimulate economic activity

- Movements in the term structure of interest rates are complex ➔ it is difficult to account for all the maturities ➔ market observers focus on a long-term rate (yield on the 10-year note) and a short-term rate (yield on a three-month bill) These two rates usefully summarize movements in the term structure

- The two rates move in tandem, although the short-term rate displays higher volatility

  Spread is defined as the difference between the long rate and the short rate

  Periods of recession usually witness an increase in the term spread ➔ slow economic activity decreases the demand for capital, which in turn decreases short-term rates and increases the term spread

FIXED INCOME RISK: VOLATILITY

- Bond returns volatility

$$\sigma\left(\frac{dP}{P}\right) = |D^*| \times \sigma(dy) \qquad (11.8)$$

- Yield volatility: $\sigma(dy)$

TABLE 11.2 U.S. Fixed-Income Return Volatility (Percent)

Type/ Maturity	Code	Yield Level	End 2006 Daily	End 2006 Mty	End 2006 Annual	End 1996 Annual
Euro-30d	R030	5.325	0.001	0.004	0.01	0.05
Euro-90d	R090	5.365	0.002	0.010	0.04	0.08
Euro-180d	R180	5.375	0.005	0.030	0.11	0.19
Euro-360d	R360	5.338	0.028	0.148	0.51	0.58
Swap-2Y	S02	5.158	0.081	0.420	1.45	1.57
Swap-3Y	S03	5.100	0.127	0.657	2.27	2.59
Swap-4Y	S04	5.062	0.172	0.890	3.08	3.59
Swap-5Y	S05	5.075	0.219	1.120	3.88	4.70
Swap-7Y	S07	5.116	0.283	1.460	5.06	6.69
Swap-10Y	S10	5.177	0.383	1.965	6.81	9.82
Zero-2Y	Z02	4.811	0.088	0.444	1.54	1.64
Zero-3Y	Z03	4.716	0.130	0.663	2.30	2.64
Zero-4Y	Z04	4.698	0.173	0.871	3.02	3.69
Zero-5Y	Z05	4.688	0.216	1.084	3.76	4.67
Zero-7Y	Z07	4.692	0.279	1.395	4.83	6.81
Zero-9Y	Z09	4.695	0.343	1.714	5.94	8.64
Zero-10Y	Z10	4.698	0.375	1.874	6.49	9.31
Zero-15Y	Z15	4.772	0.531	2.647	9.17	13.82
Zero-20Y	Z20	4.810	0.690	3.441	11.92	17.48
Zero-30Y	Z30	4.847	1.014	5.049	17.49	23.53

TABLE 11.3 U.S. Fixed-Income Yield Volatility, 2006 (Percent)

Type/ Maturity	Code	Yield Level	End 2006 Daily	End 2006 Mty	End 2006 Annual
Euro-30d	R030	5.325	0.008	0.048	0.17
Euro-90d	R090	5.365	0.006	0.041	0.14
Euro-180d	R180	5.375	0.010	0.062	0.22
Euro-360d	R360	5.338	0.030	0.157	0.54
Swap-2Y	S02	5.158	0.033	0.181	0.63
Swap-3Y	S03	5.100	0.020	0.115	0.40
Swap-4Y	S04	5.062	0.023	0.131	0.46
Swap-5Y	S05	5.075	0.022	0.132	0.46
Swap-7Y	S07	5.116	0.020	0.096	0.33
Swap-10Y	S10	5.177	0.008	0.048	0.17
Zero-2Y	Z02	4.811	0.012	0.064	0.22
Zero-3Y	Z03	4.716	0.020	0.113	0.39
Zero-4Y	Z04	4.698	0.020	0.110	0.38
Zero-5Y	Z05	4.688	0.024	0.126	0.44
Zero-7Y	Z07	4.692	0.023	0.126	0.44
Zero-9Y	Z09	4.695	0.024	0.130	0.45
Zero-10Y	Z10	4.698	0.026	0.139	0.48
Zero-15Y	Z15	4.772	0.027	0.143	0.49
Zero-20Y	Z20	4.810	0.036	0.183	0.63
Zero-30Y	Z30	4.847	0.036	0.184	0.64

FIXED INCOME RISK: CORRELATION

TABLE 11.4 U.S. Fixed-Income Return Correlations, 2006 (Daily)

	Z02	Z03	Z04	Z05	Z07	Z09	Z10	Z15	Z20	Z30
Z02	1.000									
Z03	0.991	1.000								
Z04	0.980	0.994	1.000							
Z05	0.968	0.985	0.998	1.000						
Z07	0.949	0.972	0.991	0.996	1.000					
Z09	0.934	0.960	0.982	0.990	0.998	1.000				
Z10	0.927	0.954	0.978	0.987	0.997	0.9998	1.000			
Z15	0.896	0.931	0.960	0.971	0.986	0.992	0.994	1.000		
Z20	0.874	0.913	0.944	0.958	0.976	0.983	0.985	0.998	1.000	
Z30	0.848	0.891	0.925	0.940	0.960	0.969	0.972	0.992	0.998	1.000

FIXED INCOME RISK: CORRELATION

- Yield correlations are very high ➔ common factors

- Combining Two Variables into a Single Factor: One can summarize the correlation between two variables in a scatter plot ➔ A regression line can then be fitted that represents the "best" summary of the linear relationship between the variables

- **Principal components** is a statistical technique that extracts linear combinations of the original variables that explain the highest proportion of diagonal components of the matrix (Stevens, 1986)

First principal component explains 94% of the total variance: level risk factor

Second principal component explains 4% of the total variance: slope risk factor

Third factor is found that represents a curvature risk factor

Previous research: movements in yields could be usefully summarized by two to three factors that typically explain over 95% of the total variance

FIXED INCOME RISK

- Yield is very much linked to inflation

  Low (high) Yield → low (high) expected inflation

- Most bonds are issued in nominal terms → **nominal interest rate risk**

- Recently many countries have issued inflation-protected bonds, which make payments that are fixed in real terms but indexed to the rate of inflation →the source of risk is **real interest rate risk**

- **Credit Spread Risk**: A position in a credit spread can be established by investing in credit-sensitive bonds, such as corporate and shorting Treasuries with the appropriate duration → If spread widen → very high risk → credit spreads increase in a recession and decrease in an expansion

EQUITY RISK

- Stock specific risk
- Market risk
- Stock market volatility: very high

TABLE 11.6 Equity Volatility (Percent)

Stock Market Country	Code	End 2006 Daily	End 2006 Monthly	End 2006 Annual	End 1996 Annual
Australia	AUD	0.598	3.302	11.4	13.4
Canada	CAD	0.586	3.380	11.7	13.8
Switzerland	CHF	0.606	3.212	11.1	11.1
Germany	DEM	0.701	3.616	12.5	18.6
France	FRF	0.719	3.690	12.8	16.1
Britain	GBP	0.474	2.691	9.3	11.1
Hong Kong	HKD	0.983	4.604	15.9	17.3
Japan	JPY	0.686	4.046	14.0	19.9
Korea	KRW	0.731	3.873	13.4	25.5
United States	USD	0.444	2.380	8.2	12.9
South Africa	ZAR	0.769	4.268	14.8	11.9

COMMODITY RISK

- **Commodity risk**: movements in the value of commodity contracts

  Precious metals: gold, platinum, silver (volatility similar to equity markets)

  Base metals: aluminum, copper, nickel, zinc (volatility similar to equity markets)

  Energy products: natural gas, heating oil, unleaded gasoline, crude oil (very high volatility)

- Futures risk

$$F_t e^{-r\tau} = S_t e^{-y\tau} \qquad (11.9)$$

exp(-yτ) ➔ *y* convenience yield

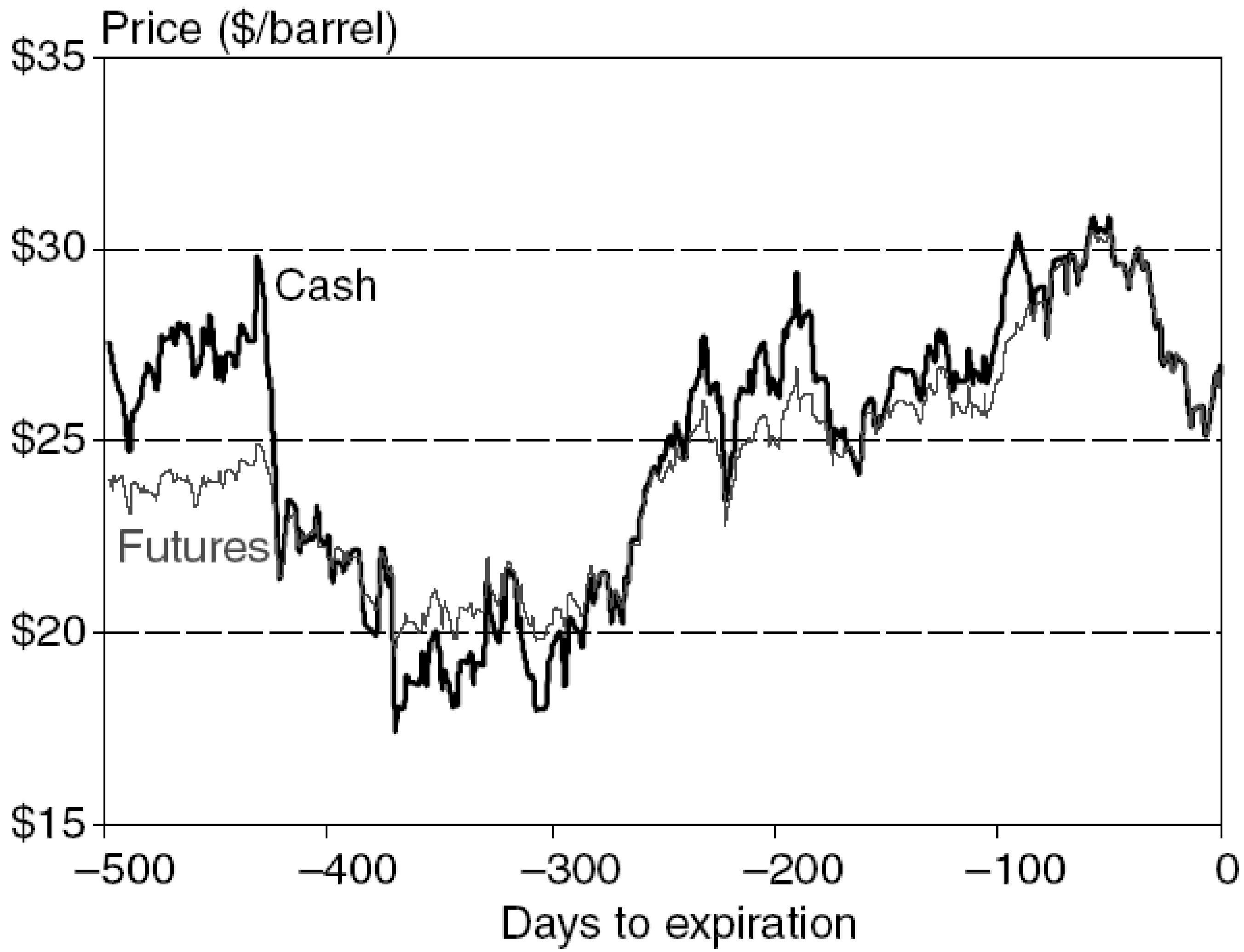
Backwardation: S > F, Contango: S < F

TABLE 11.8 Correlations across Maturities, 2006 (Daily)

Copper	COP.C00	COP.C03	COP.C15	COP.C27
COP.C00	1			
COP.C03	.998	1		
COP.C15	.979	.985	1	
COP.C27	.923	.935	.974	1

Nat.Gas	GAS.C01	GAS.C03	GAS.C06	GAS.C12
GAS.C01	1			
GAS.C03	.916	1		
GAS.C06	.897	.968	1	
GAS.C12	.884	.824	.878	1

FIGURE 11-7 Futures and Spot for Crude Oil



DIAGONAL MODEL: SHARPE

- Decompose the stock return into two components: market and stock specific

$$R_i = \alpha_i + \beta_i \times R_M + \epsilon_i \qquad (11.10)$$

Assume ε_i uncorre

$$R_p = \sum_{i=1}^{N} w_i R_i \qquad (11.12)$$

$$R_p = \sum_{i=1}^{N} (w_i \beta_i R_M + w_i \epsilon_i) = \beta_p R_M + \sum_{i=1}^{N} (w_i \epsilon_i) \qquad (11.13)$$

$$V[R_p] = \beta_p^2 V[R_M] + \sum_{i=1}^{N} \left(w_i^2 V[\epsilon_i] \right) \qquad (11.14)$$

$$\sum_{i=1}^{N} \left(w_i^2 V[\epsilon_i] \right) \rightarrow N \times [(1/N)^2 V] = (V/N)$$

➔ $V[R_p] = \beta^2{}_p V[R_M]$

DIAGONAL MODEL: SHARPE

$$\mathrm{Cov}[R_i, R_j] = \mathrm{Cov}[\beta_i R_M + \epsilon_i, \beta_j R_M + \epsilon_j] = \beta_i \beta_j \sigma_M^2 \qquad (11.20)$$

$$\mathrm{Cov}[R_i, R_i] = \beta_i^2 \sigma_M^2 + \sigma_{\epsilon,i}^2$$

$$\Sigma = \begin{bmatrix} \beta_1^2\sigma_M^2 + \sigma_{\epsilon,1}^2 & \beta_1\beta_2\sigma_M^2 & \cdots & \beta_1\beta_N\sigma_M^2 \\ \vdots & & & \\ \beta_N\beta_1\sigma_M^2 & \beta_N\beta_2\sigma_M^2 & \cdots & \beta_N^2\sigma_M^2 + \sigma_{\epsilon,N}^2 \end{bmatrix}$$

$$\Sigma = \begin{bmatrix} \beta_1 \\ \vdots \\ \beta_N \end{bmatrix} [\beta_1 \cdots \beta_N] \sigma_M^2 + \begin{bmatrix} \sigma_{\epsilon,1}^2 & \cdots & 0 \\ \vdots & & \vdots \\ 0 & \cdots & \sigma_{\epsilon,N}^2 \end{bmatrix}$$

$$\Sigma = \beta\beta'\sigma_M^2 + D_\epsilon \qquad (11.22)$$

- This consists of N elements in the vector β, N elements on the diagonal of the matrix D, plus the variance of the market itself ➔The diagonal model reduces the number of parameters from $N \times (N+1)/2$ to $2N+1$ ➔ if N = 100 from 5,050 parameters to 201 parameters

FIXED INCOME PORTFOLIO RISK

- Decompose the movements in portfolio yield into three components:

$y_i = z_j + s_k + \varepsilon_i$

z_j is the Treasury factor; s_k is credit rating factor, ε_i is the bond specific factor

Define: DVBP as the dollar value of a basis point for a risk factor

$$\Delta P_i = -\text{DVBP}_i \Delta y_i = -\text{DVBP}_i \Delta z_j - \text{DVBP}_i \Delta s_k - \text{DVBP}_i \Delta \epsilon_i \qquad (11.16)$$

$$\Delta P = -\sum_{j=1}^{J} \text{DVBP}_j^z \Delta z_j - \sum_{k=1}^{K} \text{DVBP}_k^s \Delta s_k - \sum_{i=1}^{N} n_i \text{DVBP}_i \Delta \epsilon_i$$

$$V[\Delta P] = \text{General risk} + \sum_{i=1}^{N} n_i^2 \text{DVBP}_i^2 \, V[\Delta \epsilon_i] \qquad (11.20)$$

FIXED INCOME PORTFOLIO RISK

FIGURE 11-8 Yield Decomposition