CHAPTER 13

Liquidity Risk

> LTCM then faced severe market liquidity problems when its investments began losing value and the fund attempted to unwind some of its positions.
>
> —*President's Working Group on Financial Markets, 1999*

Traditional value-at-risk (VAR) models assume that the portfolio is "frozen" over the horizon and that market prices represent achievable transaction prices. This marking-to-market approach is adequate to quantify and control risk for an ongoing portfolio but may be more questionable if VAR is supposed to represent the worst loss over a liquidation period.

The question is how VAR can be adapted to deal with liquidity considerations. As we saw in Chapter 1, liquidity risk can be grouped into *funding liquidity risk* and *asset liquidity risk.* Funding liquidity risk arises when financing cannot be maintained owing to creditor or investor demands. The resulting need for cash may require selling assets. Asset liquidity risk arises when a forced liquidation of assets creates unfavorable price movements. Thus liquidity considerations should be viewed in the context of both the assets and the liabilities of the financial institution.

This chapter discusses recent developments that adapt traditional VAR measures to liquidity considerations. Section 13.1 first provides a general introduction to asset and funding liquidity risk.

Next, Section 13.2 attempts to incorporate asset liquidity risk into VAR measures. Immediate liquidation can create losses owing to market impact, which is a drop in the liquidation value relative to mark-to-market prices. Liquidation, however, can take place over many days and should be done so as to balance transactions costs and price risk. Taking both costs and risk into account leads to a measure of liquidity-adjusted VAR (LVAR). Often, however, liquidity is factored into the valuation of positions by decreasing their value by a reserve.

Section 13.3 then discusses measures of funding liquidity risk proposed by the Counterparty Risk Management Policy Group (CRMPG). Even though an institution can have zero traditional VAR, different swap credit terms can generate different cash requirements. The cash liquidity measure is an extension of VAR.

Next, Section 13.4 is devoted to an analysis of the Long-Term Capital Management (LTCM) debacle. LTCM failed because of its lack of diversification combined with its asset and funding liquidity risk, which were due to its sheer size.

Finally, Section 13.5 provides some concluding comments about liquidity risk. Liquidity problems have proved to be crucial in the failure of many financial institutions. Liquidity risk can be factored formally into hybrid VAR measures but only using price impact functions derived from normal market conditions. During episodes of systemic risk, however, liquidity evaporates, invalidating much of this analysis. Thus liquidity risk probably is the weakest spot of market risk management systems.

13.1 DEFINING LIQUIDITY RISK

Table 13-1 displays sources of liquidity risk for a financial institution. Liquidity risk emanates from the liability side, when creditors or investors demand their money back. This usually happens after the institution has incurred or is thought to have incurred losses that could threaten its solvency. The need for cash creates problems on the asset side when the forced liquidation of assets causes transactions losses.

Understanding liquidity risk requires knowledge of several different fields, including *market microstructure*, which is the study of market-

TABLE 13-1

Sources of Liquidity Risk

Assets	Liabilities
Size of position	Funding
Price impact for unit trade	Mark to market, haircuts
	Equity
	Investor redemptions

clearing mechanisms; *optimal trade execution*, which is the design of strategies to minimize trading costs or to meet some other objective function; and *asset-liability management*, which attempts to match the values of assets and liabilities on balance sheets.

13.1.1 Asset Liquidity Risk

Asset liquidity risk, sometimes called *market/product liquidity risk*, is the risk that the liquidation value of assets may differ significantly from their current mark-to-market values. It is a function of the price impact of trades and the size of the positions.

Asset liquidity can be measured by a price-quantity function. This is also known as the *market-impact* effect. Highly liquid assets, such as major currencies or Treasury bonds, are characterized by *deep markets*, where positions can be offset with very little price impact. *Thin* markets, such as exotic over-the-counter (OTC) derivatives contracts or some emerging market equities, are those where any transaction can quickly affect prices.

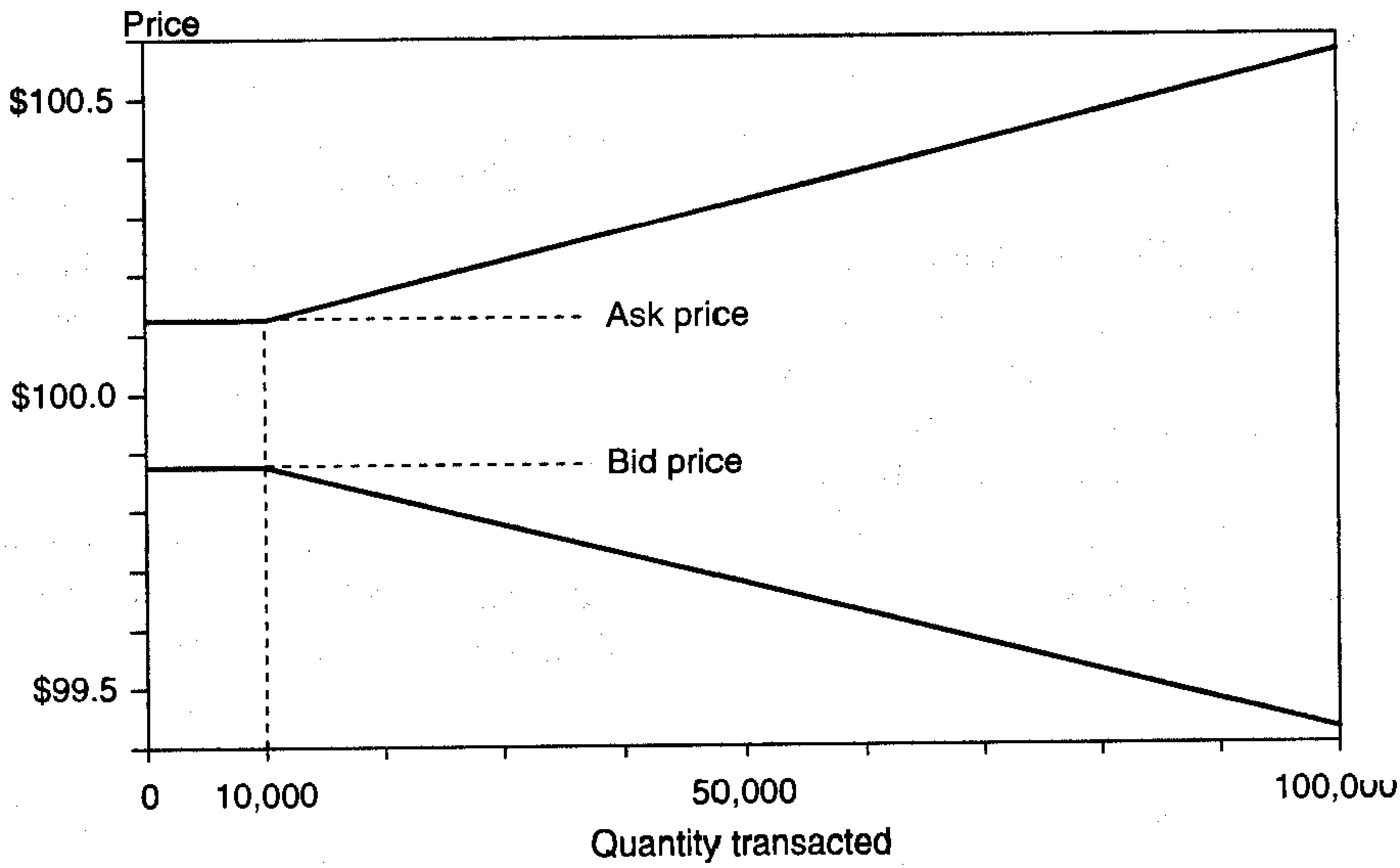
This price function is illustrated in Figure 13-1.[1] The starting point is the current *midprice*, which is the average of the bid and ask quotes and can be used to mark the portfolio to market. Here, the *bid-ask spread* is \$0.25. Markets with low spreads are said to exhibit *tightness*. In Figure 13-1, this is valid up to some limit, say, 10,000 shares. This is sometimes called the *normal market size*, or *depth*. Relative to mid-market values, the cost of trading is half the spread. This component of trading cost is sometimes called *exogenous* because it does not depend on quantities transacted, as long as these quantities are below the normal market size.

For quantities beyond this point, however, the sale price is a decreasing function of the quantity, reflecting the price pressure required to clear the market. The converse is true for the purchase price. In practice, the position is compared with some metric such as the median daily trading volume. For a widely traded stock such as IBM, for instance, selling 4 percent of the daily trading volume incurs a cost of about 60 basis points. Studies of market microstructure provide empirical evidence on trading costs.

[1] In what follows, we ignore the fixed component of trading costs, that is, commissions and taxes.

FIGURE 13-1

Price-quantity function.



This relationship is assumed to be linear, although it could take another shape. The slope of the line measures the *market impact.* This varies across assets and, possibly, across time for a given asset. In this example, selling 100,000 shares over 1 day would push the price down from a midmarket value of \$100 to about \$99.4. Thus, selling this position would incur a liquidation cost of (\$100−\$99.4)/\$100, or 60 basis points.

This demonstrates that liquidity depends on both the price-impact function and the size of the position. In this example, if the position is below 10,000 shares, then market liquidity is not a major issue. In contrast, if the institution holds a number of shares worth several days of normal trading volume, liquidity should be of primary concern.

In addition to varying across assets, liquidity is also a function of prevailing market conditions. This is more worrying because markets seem to go through regular bouts of liquidity crises. Most notably, liquidity in bond markets dried up during the summer of 1998 as uncertainty about defaults led to a "flight to quality," that is, increases in the prices of Treasuries relative to those of other bonds. A similar experience occurred during the 1994 bond market debacle, at which time it became quite difficult to deal in Eurobonds or mortgage-backed securities.

Traditionally, asset liquidity risk has been controlled through position limits. The goal of *position limits* is to limit the exposure to a single instrument, even if it provides diversification of market risk, in order to avoid a large market impact in case of forced liquidation.

13.1.2 Funding Liquidity Risk

Cash-flow/funding liquidity risk refers to the inability to meet payment obligations to creditors or investors. This can force unwanted liquidation of the portfolio.

Funding risk arises from the liability side of the balance sheet. Most financial institutions are *leveraged*. Often, this involves posting some collateral (assets) in exchange for cash from a broker. Normally, brokers require collateral that is worth slightly more than the cash loaned, by an amount known as a *haircut*, designed to provide a buffer against decreases in the collateral value. The value of the collateral, however, is constantly *marked to market* by the broker. If this value falls, the broker will require some additional payment, called *variation margin*, to keep the total amount held above the loan value. If the institution does not have enough cash on hand, it will be forced to liquidate some of its other assets.

Brokers also reserve the right of *changes in collateral requirements*, which can create additional cash flow risk. For example, brokers can increase the haircut when markets are more volatile, creating extra demands on cash. Similarly, organized exchanges can change their required margins at will.

Finally, cash-flow liquidity risk also arises owing to *mismatches in the timing of payments*. Even if an institution is perfectly matched in terms of market risk, it may be forced to make a payment on a position without having yet received an offsetting payment on a hedge. Section 13.3 gives examples of such mismatches.

The first line of defense against funding liquidity risk is *cash*. Another may be a *line of credit*, which is a loan arrangement with a bank allowing the customer to borrow up to a prespecified amount.

The institution may be able to meet margin calls by raising funds from another source, such as new debt or a new equity issue. In practice, it may be difficult to raise new funds precisely when the institution is faring badly and needing them most.

Conversely, the institution must evaluate the likelihood of redemptions, or cash requests from debt holders or equity holders. This is most likely to occur when the institution appears most vulnerable, thereby transforming what could be a minor problem into a crisis. It is also important to avoid debt covenants or options that contain "triggers" that would force early redemption of the borrowed funds. Such credit triggers accelerated the fall of Enron, as shown in Box 13-1.

BOX 13-1

ENRON'S CREDIT TRIGGERS: THE BAD AND STUPID

Credit triggers are clauses in financial contracts that allow creditors to demand immediate payments if the credit rating of the borrower falls below some predetermined level.

Enron is now widely viewed as a massive case of accounting fraud. Credit triggers, however, played a role in Enron's demise. Enron was rated investment-grade until November 28, 2001, when a proposed takeover by Dynergy fell through. On that day, Standard & Poor's downgraded Enron to speculative-grade, triggering the immediate repayment of almost $4 billion in debt. Unable to pay, Enron filed for bankruptcy on December 2, 2001.

The real cause of Enron's failure was its poor performance in many business lines, which was hidden through creative off-balance-sheet financing. As early as 1999, Vince Kaminsky, Enron's risk manager, had railed against these arrangements, which he said had gone from merely "stupid" to fraudulent. His comments, unfortunately, were ignored by top management.

Ostensibly, credit triggers are designed to lower the cost of capital for the issuing company. Because this is an option granted to debt holders, they should be willing to accept a lower interest rate than otherwise. Superficially, such clauses look beneficial because lenders can *put* the obligation back to the borrower.

In practice, however, there have been many cases where credit triggers offered no protection to creditors because they precipitated a default. In such situations, from the viewpoint of borrowers, the cost savings have been swamped by the problems caused by credit triggers.

Credit-rating agencies call these credit triggers "problematic" and "troubling." As a result, they now examine much more closely the potential effects of credit triggers and take them into account when setting ratings.*

* See Moody's (2001).

Thus liquidity considerations should be viewed in the context of both asset and liabilities. Consider, for instance, *hedge funds*, some of which invest in illiquid assets such as distressed debt. To minimize liquidity risk, such funds impose a longer *lockup period*, or minimum time for investors to keep their funds, and a longer *redemption notice period* for withdrawing funds.

As explained in Chapter 3, *commercial banks* are by their nature susceptible to liquidity risks. They are funded by short-term deposits but can invest in illiquid real estate loans. This setup is fraught with liquidity risk and explains the rationale for deposit insurance, which eliminates the incentives for bank runs.

13.2 ASSESSING ASSET LIQUIDITY RISK

Trading returns are measured typically from midmarket prices. This may be adequate for measuring daily profit and loss (P&L) but may not represent the actual fall in value if a large portfolio were to be liquidated. The question is how to assess potential losses under such conditions.[2] In turn, this can give insights into how to manage this risk.

Traditional adjustments are done on an ad hoc basis. Liquidity risk can be loosely factored into VAR measures by ensuring that the *horizon* is at least greater than an orderly liquidation period. Generally, the same horizon is applied to all asset classes, even though some may be more liquid than others.

Sometimes, longer liquidation periods for some assets are taken into account by artificially increasing the volatility. For instance, one could mix a large position in the dollar/yen with another one in the dollar/Polish zloty, both of which have an annual volatility of 10 percent, by artificially increasing the volatility of the second foreign currency in the VAR computations.

13.2.1 Effect of Bid-Ask Spreads

More formally, one can focus on the various components of liquidation costs. The first and most easily measurable is the quoted bid-ask spread, defined in relative terms, that is,

[2] Note that the section is titled "Assessing Asset Liquidity Risk" instead of "Measuring Asset Liquidity Risk." This is to reflect the fact that assessment is less precise than measurement.

$$S = \frac{[P(\text{ask}) - P(\text{bid})]}{P(\text{mid})} \tag{13.1}$$

Table 13-2 provides typical spreads. We see that spreads vary from a low of about 0.05 percent for major currencies, large U.S. stocks, and on-the-run Treasuries to much higher values when dealing with less liquid currencies, stocks, and bonds. Treasury bills are in a class of their own, with extremely low spreads. These spreads are indicative only because they depend on market conditions. Also, market makers may be willing to trade within the spread.

At this point, it is useful to review briefly the drivers of these spreads. According to market microstructure theory, spreads reflect three different types of costs:

- *Order-processing costs* cover the cost of providing liquidity services and reflect the cost of trading, the volume of transaction, the state of technology, and competition. With fixed operating costs, these order-processing costs should decrease with transaction volumes.

TABLE 13-2

Typical Spreads and Volatility

		Volatility (%)	
Asset	**Spread (%) (Bid-Ask)**	**Daily**	**Annual**
Currencies			
Major (euro, yen, . . .)	0.02–0.10	0.3–1.0	5–15
Emerging (floating)	0.10–1.00	0.3–1.9	5–30
Bonds			
On-the-run Treasuries	0.03	0.0–0.7	0–11
Off-the-run Treasuries	0.06–0.20	0.0–0.7	0–11
Corporates	0.10–1.00	0.0–0.7	0–11
Treasury bills	0.003–0.02	0.0–0.1	0–1
Stocks			
U.S.	0.05–5.00	1.3–3.8	20–60
Average, NYSE	0.20	1.0	15
Average, all countries	0.40	1.0–1.9	15–30

Note: Author's calculations. Cost of trades excludes broker commissions and fees. See also *Institutional Investor* (November 1999).

- *Asymmetric-information costs* reflect the fact that some orders may come from informed traders, at the expense of market makers who can somewhat protect themselves by increasing the spread.
- *Inventory carrying costs* are due to the cost of maintaining open positions, which increase with higher price volatility, higher interest-rate carrying costs, and lower trading activity or turnover.

If the spread were fixed, one simply could construct a liquidity-adjusted VAR from the traditional VAR by adding a term, that is,

$$\text{LVAR} = \text{VAR} + L_1 = (W\alpha\sigma) + 1/2(WS) \qquad (13.2)$$

where W is the initial wealth, or portfolio value. For instance, if we have \$1 million invested in a typical stock with a daily volatility of $\sigma = 1$ percent and spread of $S = 0.20$ percent, the 1-day LVAR at the 95 percent confidence level would be

$$(\$1{,}000{,}000 \times 1.645 \times 0.01) + 1/2\,(\$1{,}000{,}000 \times 0.0020)$$
$$= \$16{,}450 + \$1000 = \$17{,}450$$

Here, the correction factor is relatively small, accounting for 7 percent of the total.

This adjustment can be repeated for all assets in the portfolio, leading to a series of add-ons, $1/2\,\Sigma_i |W_i| S_i$. This sequence of positive terms increases linearly with the number of assets, whereas the usual VAR benefits from diversification effects. Thus the relative importance of the correction factor will be greater for large portfolios.

A slightly more general approach is proposed by Bangia et al. (1999), who consider the uncertainty in the spread. They characterize the distribution by its mean $\overline{S}$ and standard deviation σ_S. The adjustment considers the worst increase in the spread at some confidence level, that is,

$$\text{LVAR} = \text{VAR} + L_2 = (W\alpha\sigma) + \tfrac{1}{2}[W(\overline{S} + \alpha'\sigma_s)] \qquad (13.3)$$

This assumes that the worst market loss and increase in spread will occur simultaneously. In general, we observe a positive correlation between volatility and spreads.

At the portfolio level, one theoretically could take into account correlations between spreads. In practice, summing the individual worst spreads provides a conservative measure of the portfolio worst spread.

Typically, σ_s is about half the size of the average spread; for example, $\sigma_s = 0.02$ percent against $\bar{S} = 0.04$ percent for the dollar/euro exchange rate. Relative to a volatility of about 1.0 percent per day, these adjustments are small. Thus transactions costs based on spreads are not very important relative to usual VAR measures.

13.2.2 Incorporating Liquidity in Valuation

If the position is to be sold, the second term in Equation (13.2) represents a certain loss, unlike the volatility term. Assuming that the portfolio is valued using midmarket prices, it represents the loss owing to the liquidation.

Another approach to liquidity is to mark the portfolio to the appropriate bid prices (for long positions) or ask prices (for short positions). In practice, financial institutions generally mark their cash positions to the conservative bid-offer basis.[3] VAR then can be viewed as the worst loss from this value.

Further, financial institutions often apply *reserves*, which are pricing changes in the valuation away from fair value to account for such effects as illiquidity and model risk. Firms deduct this reserve from the fair value of positions to account for the extra time and cost required to close out the position. The reserve amount is often based on judgments about the liquidity of a market. In such cases, there is no need to take liquidity risk into account in VAR because it is already factored into the valuation of positions.

13.2.3 Effect of Price Impact

Although this approach has the merit of considering some transactions costs, it is not totally satisfactory. It only looks at the bid-ask spread component of these costs, which may be appropriate for a small portfolio but certainly not when liquidation can affect market prices. The market-impact factor should be taken into account.

To simplify, let us assume a linear price-quantity function and ignore the spread. For a sale, the price per share is

$$P(q) = P_0(1 - kq) \tag{13.4}$$

[3] See the Basel Committee (2005a) survey of financial institutions. Derivatives, however, generally are marked to midmarket values.

Assume that $P_0 = \$100$ and $k = 0.5 \times 10^{-7}$. Say that we start with a position of $q = 1$ million shares of the stock. If we liquidate all at once, the price drop will be $P_0 kq = \$100 \times (0.5 \times 10^{-7}) \times 1{,}000{,}000 = \$5$ per share, leading to a total price impact of \$5 million. In contrast, we could decide to work the order through at a constant rate of 200,000 shares over $n = 5$ days. In the absence of other price movements, the daily price drop will be \$1 per share, leading to a total price impact of \$1 million, much less than before.

Immediate liquidation creates the costs:

$$C_1(W) = q \times [P_0 - P(q)] = q \times (P_0 - P_0 + P_0 kq) = kq^2 P_0 \quad (13.5)$$

Uniform liquidation creates the costs:

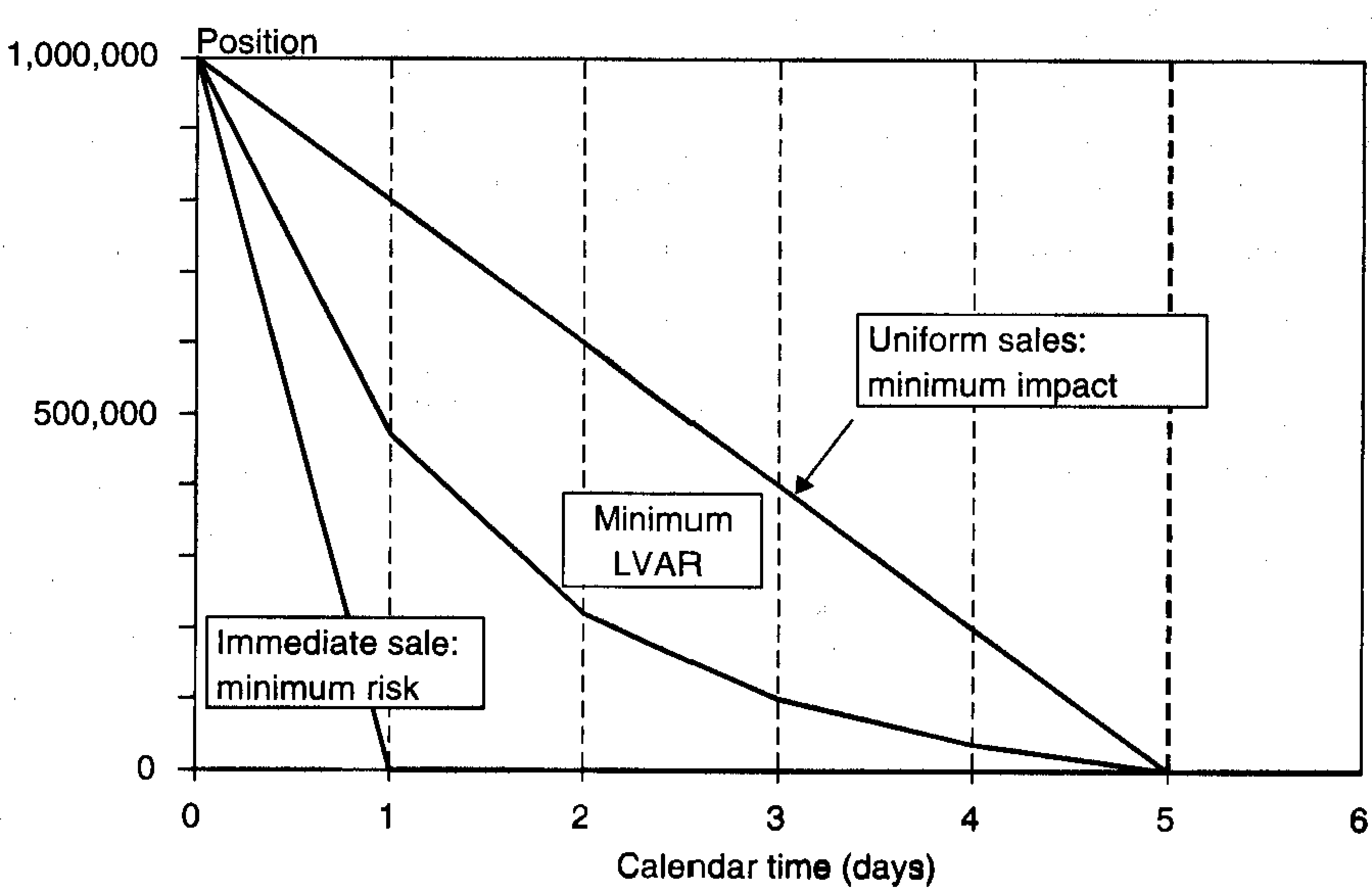
$$C_2(W) = q \times [P_0 - P(q/n)] = q \times (P_0 - P_0 + P_0 kq/n) = k(q^2/n) P_0 \quad (13.6)$$

Because uniform liquidation spreads the price impact over many days, it leads to lower trading costs.

The drawback of liquidating more slowly, however, is that the portfolio remains exposed to price risks over a longer period. The position profiles are compared in Figure 13-2. Under the immediate sale, the

FIGURE 13-2

Profile of execution strategies.



position is liquidated before the end of the next day, leading to a high cost but minimum risk. Under the uniform sale, the position is sold off in equal-sized lots, leading to low costs but higher volatility.

To analyze the risk profile of these strategies, define σ as the daily volatility of the share price, in dollars. We assume that sales are executed at the close of the business day in one block. Hence, for the immediate sale, the price risk, or variance of wealth, is zero, that is, $V_1(W) = 0$.

For the uniform sale, assume that returns are independent over each day so that the total variance is the sum of the daily variances. The relative positions are defined as $x_0, x_1, \ldots, x_n$. At the end of the first day, the position will have decreased from $x_0 = 1$ to $x_1 = [1 - (1/n)]$. The next day, it will have gone to $[1 - 2\,(1/n)]$ and so on. With uncorrelated daily returns, the total portfolio variance over n days is the sum of the variance over each day, that is,

$$V_2(W) = \sigma^2 q^2 \left\{ \left(1 - \frac{1}{n}\right)^2 + \left(1 - 2\frac{1}{n}\right)^2 + \cdots + \left[1 - (n-1)\frac{1}{n}\right]^2 \right\} P_0^2 \qquad (13.7)$$

This can be simplified to

$$V_2(W) = \sigma^2 q^2 \left[n\frac{1}{3}\left(1 - \frac{1}{n}\right)\left(1 - \frac{1}{2n}\right) \right] \mathrm{P}_0^2 = \sigma^2 q^2 T^* P_0^2 \qquad (13.8)$$

For example, with $n = 5$, the correction factor between brackets is $T^* = 1.20$. Thus the risk of a strategy of uniform liquidation over 5 days is equivalent to the mark-to-market risk of a position held over 1.2 days. It is interesting to note that the 10-day fixed horizon dictated by the Basel Committee is equivalent to a constant liquidation over 31 trading days.

Adding transactions costs leads to a liquidity-adjusted VAR, defined as

$$\text{LVAR} = \alpha\sqrt{V(W)} + C(W) \qquad (13.9)$$

where α corresponds to the confidence level c. Lawrence and Robinson (1997), for instance, propose choosing n to minimize LVAR.

13.2.4 Trading Strategies

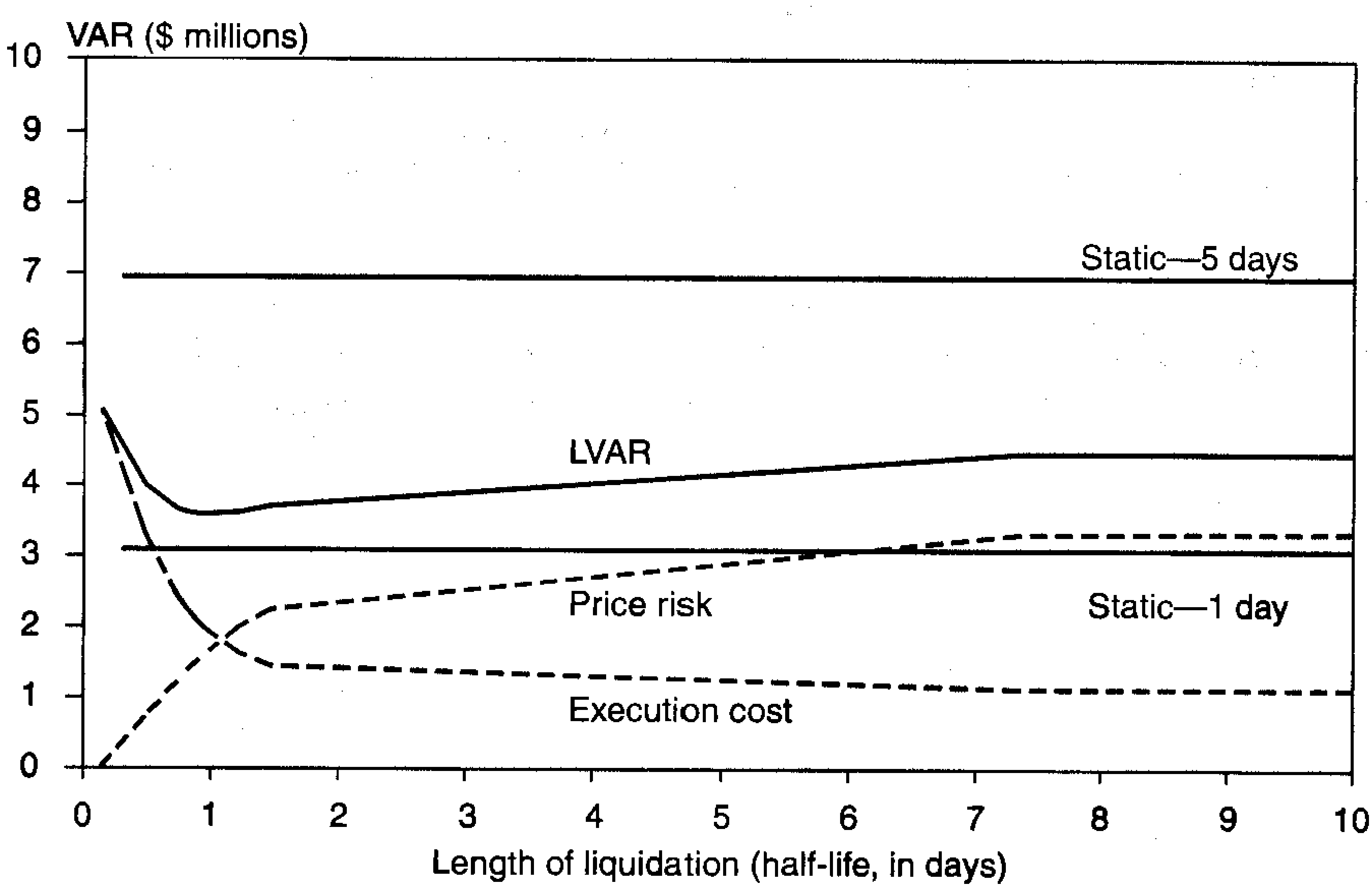
Execution strategies need not be limited to these two extreme cases—immediate or uniform liquidation. More generally, we can choose a strategy, or pattern of daily positions that leads to an optimal tradeoff between execution costs and price risk. Almgren and Chriss (2001) provide useful closed-form solutions for efficient execution strategies. Their paper is an important contribution that helped lay the groundwork for *algorithmic trading* on Wall Street.[4]

An optimal trajectory is described in Figure 13-2. This is defined by a set of daily positions $x_0, x_1, x_2, \ldots, x_n$. On the first day, the optimal position drops by more than the uniform sale: $x_0 - x_1 > 1/n$. Intuitively, this is so because it helps lowering price risk over the total horizon. Note that the strategy can be described by its *half-life*, which is the time required to liquidate half the portfolio. In this case, this takes 1 day.

Figure 13-3 compares various VAR measures for different speeds of execution. The "static" 1- and 5-day VARs correspond to the usual mark-to-market VAR measures with 30 percent annual volatility at the

FIGURE 13-3

Liquidity-adjusted VAR.



[4] *Algorithmic trading* is commonly defined as the automatic slicing of trading orders according to a predefined strategy to meet a specific benchmark. Estimates suggest that 60 percent of U.S. buy-side firms now use algorithmic trading. The increase in algorithmic trading, combined with the decimalization of bid-ask spreads, explains why trade sizes are getting smaller on U.S. exchanges. Algorithmic trading slices trades into small pieces, preserving anonymity and decreasing price impact. These methods, however, are most effective when trading liquid stocks, for which the price-impact function can be measured reasonably accurately.

95 percent level of confidence. Under these conditions, the daily volatility is 1.9 percent, and the 1-day VAR is $1.645 \times 0.019 \times \$100 = \$3.1$ million for this \$100 million portfolio, assuming a normal distribution. Under liquidation, however, we have to account for market impact.

The LVAR measure incorporates the total execution-cost and price-risk components in a consistent fashion. As we extend the length of liquidation, the execution-cost component decreases, but the price-risk component increases. Here, the total LVAR is minimized at a half-life of 1 day. In this case, a 5-day static VAR would provide a conservative measure of liquidation VAR.

The real benefit of this approach is that it draws attention to market-impact effects in portfolio liquidation. It also illustrates that execution strategies should pay close attention to execution costs and price volatility.

Other strategies can be used for liquidation. In the case of stock portfolios, for instance, the portfolio manager could cut the price risk by immediately putting in place a hedge with stock-index futures. In this case, the remaining price risk is "specific" to the security. Orders to sell then could be transmitted so as to minimize their price impact.

13.2.5 Example

In practice, the computational requirements to adjust the conventional VAR numbers are formidable. The method requires a price-quantity function for all securities in the portfolio. Combined with the portfolio position, this yields an estimate of the price impact of a liquidation.

Table 13-3 provides an example of such an analysis, as provided by Morgan Stanley for a four-country \$50 million equity portfolio. The data for Switzerland are expanded at the individual-stock level. To estimate the total impact cost, we need information about the historical bid-ask spreads, the median trading volume, and recent volatility. The portfolio relative size then is defined as the number of shares held as a percentage of median trading volume. The total impact cost then is computed as a function of half the bid-ask spread, the price-impact function, and the size of the position.

Here, the total cost of immediate (1-day) liquidation is estimated to be 21.5 basis points. This can be compared with the daily mark-to-market volatility of this portfolio, which is 110 basis points. Using Equation (13.9), if the portfolio were to be liquidated at the end of the next day, the worst LVAR loss at the 95 confidence percent level would be about $\$50 \times (1.645 \times 0.011 + 0.0022) = \$0.9$ million + \$0.1 million. This adds up to \$1.0

TABLE 13-3

Market Impact-Cost Report

	Portfolio			Cost Analysis			
Asset	**Value (US$)**	**Shares Held**	**Price**	**Spread (bp)**	**Median Volume**	**Shares/ Volume**	**Impact Cost (bp)**
France	19,300,182	184,063	104.9	19.9		1.3%	18.2
Germany	19,492,570	322,550	60.4	26.1		2.5%	29.3
U.K.	5,860,371	424,373	13.8	20.2		0.6%	17.6
Switzerland	5,351,851	9,355	572.1	12.5		1.1%	9.5
Novartis	2,369,367	1,630	1,453.6	11.7	123,554	1.3%	8.8
Swatch	64,678	400	161.7	32.9	42,559	0.9%	15.5
Nestle	1,752,009	935	1,873.8	6.4	76,004	1.2%	7.3
CS Group	1,165,797	6,390	182.4	22.2	978,168	0.7%	14.1
Total	50,004,974	940,341	53.2	21.6		1.7%	21.5

Source: Morgan Stanley (1999).

million, most of which is price risk. The relative importance of liquidity no doubt would be much greater for a larger portfolio.

13.3 ASSESSING FUNDING LIQUIDITY RISK

Assessing funding liquidity risk involves examining the asset-liability structure of the institution and potential demands on cash and other sources of liquidity. Some lessons are available from the Counterparty Risk Management Policy Group (1999), which was established in the wake of the LTCM near failure to strengthen practices related to the management of market, counterparty credit, and liquidity risk.[5]

The CRMPG proposes to evaluate funding risk by comparing the amount of cash an institution has at hand with to what it could need to meet payment obligations. It defines *cash liquidity* as the ratio of cash equivalent over the potential decline in the value of positions that may create cash-flow needs.

[5] The CRMPG consists of senior-level practitioners from the financial industry, including many banks that provided funding to LTCM.

TABLE 13-4

Computing Funding Liquidity Ratio

	Case 1	Case 2
Assets		
Cash	$5	$5
Liabilities		
Equity	$5	$5
Derivatives		
Long 10-year swap	$100, two-way mark to market	$100, unsecured
Short 10-year swap	$100, two-way mark to market	$100, two-way mark to market
Cash equivalent	$5	$5
Funding VAR	$1.1 (1-day)	$3.5 (10-day)
Ratio	4.5	1.4

Suppose that an institution has two swap positions that identically offset each other with two different counterparties. Thus there is no market risk, and the usual VAR is zero. The swaps are structured with different credit terms, however. Table 13-4 summarizes the positions.

In Case 1, each position is a *two-way mark-to-market* swap, also called *bilateral mark-to-market*. Because the two swaps are both marked to market, any cash payment in one swap must be offset by a receipt on the other leg. The only risk is that of a delay in the receipt, say, over 1 day. Assume that the worst move on a $100 million swap at the 99 percent level over 1 day is $1.1 million. Since this is the worst cash need, the funding ratio is $5/$1.1 = 4.5, which indicates sufficient cash coverage.

In Case 2, one of the positions is an unsecured *one-way mark-to-market* swap. Under this arrangement, the institution is required to make payments if the position loses money; it will not, however, receive intermediate payments if the position gains. Because of this asymmetry, the institution is subject to mismatches in the timing of collateral payments if the first swap loses money. We now need to consider a longer horizon, say, 10 days. This gives a VAR of $3.5 million and a funding ratio of 1.4. This seems barely enough to provide protection against funding risk. Thus some of the elements of traditional VAR can be used to compute funding risk, which can be quite different from market risk when the institution is highly leveraged. Box 13-2 illustrates how credit-rating agencies evaluate liquidity risk.

BOX 13-2

HOW RATING AGENCIES ASSESS LIQUIDITY RISK

Liquidity risk is an important component of the risk of a trading operation. Credit-rating agencies do take this risk into account when assessing the credit risk of an institution with a large trading desk.

Standard & Poor's defines *liquidity risk* as the risk that a trading operation's need for cash collateral may exceed its total liquidity resources. Exposure to collateral calls is evaluated under a stress scenario where the institution is downgraded to a speculative rating. Standard & Poor's then determines whether the institution has sufficient dedicated liquidity resources to cover these collateral calls.

The size of the worst collateral calls is estimated by the sum of all positions that have negative market values. This is so because positions with positive values are not subject to margin calls. For instance, if an institution owes $1 million to each of counterparties A and B but is owed $5 million each by counterparties C and D, it may have to post $2 million in the worst-case scenario. This is so because collateral is not transferable. In other words, even if the institution held $10 million from C and D, these funds could not be used to honor margin calls from A and B. When setting its credit rating, Standard & Poor's estimates the probability that the institution would not be able to post $2 million in the worst-case scenario.

13.4 LESSONS FROM LTCM

The story of Long-Term Capital Management (LTCM) provides a number of lessons in liquidity risk. LTCM was founded by John W. Meriwether in 1994, who left Salomon Brothers after the 1991 bond scandal. Meriwether took with him a group of traders and academics and set up a hedge fund that tried to take advantage of "relative value," or "convergence arbitrage" trades, betting on differences in prices, or spreads, among closely related securities.

13.4.1 LTCM's Leverage

Since such strategies tend to generate tiny profits, leverage has to be used to create attractive returns. By December 1997, the total equity in the fund was $5 billion. LTCM's balance sheet was about $125 billion.

This represented an astonishing leverage ratio of 25:1. Even more astonishing was the off-balance-sheet position, including swaps, options, and other derivatives, that added up to a notional amount of $1.25 trillion. This represents the total of *gross positions*, measured as the sum of the absolute value of the trade's notional principal amounts.

To give an idea of the magnitude of these positions, the Bank for International Settlements reported a total swap market of $29 trillion in 1998. Hence LTCM's swap positions accounted for 2.4 percent of the global swap market. Many of these trades, however, were offsetting each other, so this notional amount is practically meaningless. What mattered was the net risk of the fund. LTCM, however, failed to appreciate that these gross positions were so large that attempts to liquidate them would provoke large market moves.

13.4.2 LTCM's "Bulletproofing"

LTCM was able to leverage its balance sheet through sale-repurchase agreements (repos) with commercial and investment banks. Under *repo* agreements, the fund sold some of its assets in exchange for cash and a promise to repurchase them back at a fixed price at some future date. Normally, the value of the assets or collateral exceeds the cash loaned, by an amount known as a *haircut*, which creates a limit to the leverage. LTCM, however, was able to obtain unusually good financing conditions, with next-to-zero haircuts, because it was widely viewed as "safe" by its lenders. In addition, the swaps were subject to two-way marking to market.

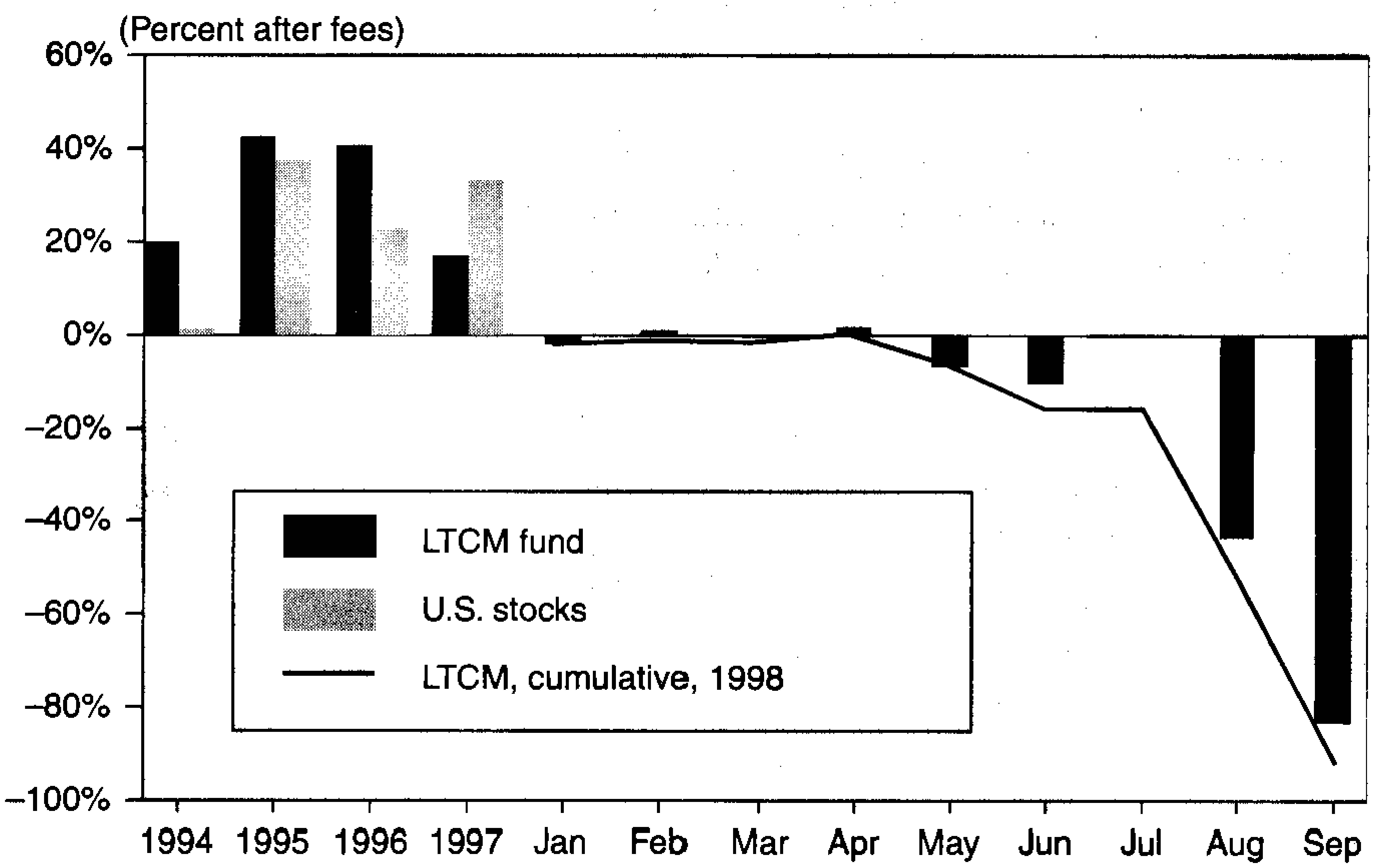
On the supply side, LTCM had "bulletproofed" itself against a liquidity squeeze. LTCM initially had required investors to keep their money in the fund for a minimum of 3 years. The purpose of this so-called lockup clause was to avoid forced sales in case of poor performance. LTCM also secured a $900 million credit line from Chase Manhattan and other banks. Even though LTCM had some protection against funding liquidity risk, it was still exposed to market risk and asset-liquidity risk.

13.4.3 LTCM's Downfall

LTCM's strategy profited handsomely from the narrowing of credit spreads during the early years, leading to after-fees returns above 40 percent, as shown in Figure 13-4. Troubles began in May and June of 1998. A

FIGURE 13-4

LTCM's returns.



downturn in the mortgage-backed securities market led to a 16 percent loss in LTCM's capital. Then came August 17. Russia announced that it was "restructuring" its bond payments—de facto defaulting on its debt. This bombshell led to a reassessment of credit and sovereign risks across all financial markets. Credit spreads, risk premiums, and liquidity spreads jumped up sharply. Stock markets dived. LTCM lost \$550 million on August 21 alone.

By August, the fund had lost 52 percent of its December 31 value. With assets still at \$126 billion, the leverage ratio had increased from 28:1 to 55:1. LTCM badly needed new capital. It desperately tried to find new investors, without success.

In September, the portfolio's losses accelerated. Bear Stearns, LTCM's prime broker, faced a large margin call from a losing LTCM T-bond futures position. It then required increased collateral, which depleted the fund's liquid resources.

LTCM now was caught in a squeeze between *funding risk*, as its reserves dwindled, and *asset risk*, as the size of its positions made it impractical to liquidate assets.

A liquidation of the fund would have forced the brokers to sell off tens of billions of dollars of securities and to cover their numerous derivatives trades with LTCM. Because lenders had required next-to-zero haircuts, there was a potential for losses to accrue while the collateral was being liquidated. In credit risk terms, lenders had low current exposure but significant *potential exposure*.

The potential disruption in financial markets was such that the New York Federal Reserve felt compelled to act. On September 23, it organized a bailout of LTCM, encouraging 14 banks to invest $3.6 billion in return for a 90 percent stake in the firm. These fresh funds came just in time to avoid meltdown. By September 28, the fund's value had dropped to $400 million only. LTCM investors had lost a whopping 92 percent of their year-to-date investment.

13.4.4 LTCM's Liquidity

LTCM failed because of its inability to manage its risk. This was due in no small part to the fact that LTCM's trades were rather undiversified. LTCM was reported to have lost about $1.5 billion from interest-rate swap positions and a similar amount from short positions on equity volatility. As we will show in Chapter 21, this was a result of an ill-fated attempt to manage risk through portfolio optimization.

Table 13-5 describes the exposure of various reported trades to fundamental risk factors. All the trades were exposed to increased market volatility. Most were exposed to increased liquidity risk (which is itself

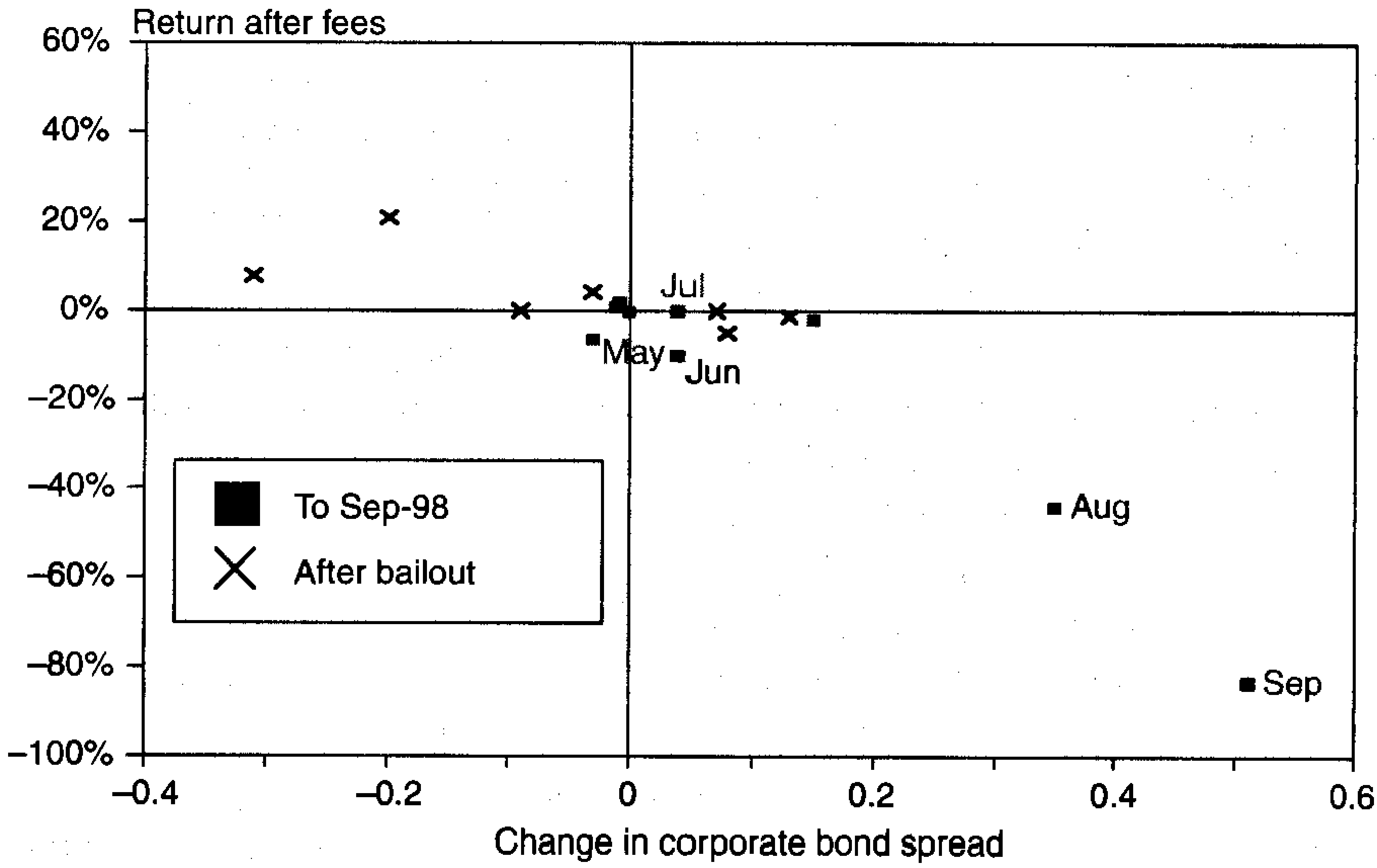
TABLE 13-5

Exposure of LTCM's Portfolio to Risk Factors

	Loss if Risk Factor Increases		
Trade	**Volatility**	**Default**	**Illiquidity**
Long interest-rate swap	Yes	Yes	Yes
Short equity options	Yes		
Long off-the-run/short on-the-run Treasuries			Yes
Long mortgage-backed securities (hedged)	Yes		Yes
Long sovereign debt	Yes	Yes	Yes

FIGURE 13-5

Explaining LTCM's returns.



positively correlated with volatility). Many were exposed to increased default risk.

To illustrate the driving factor behind LTCM's risks, Figure 13-5 plots the monthly returns against monthly changes in credit spreads. The fit is remarkably good, indicating that a single risk factor would explain 90 percent of the variation up to the September bailout. Thus there was little diversification across risk factors.

In addition, LTCM was a victim of both asset and funding liquidity risk. Although it had taken some precautions against withdrawal of funds, it did not foresee that it would be unable to raise new funds as its performance dived. The very size of the fund made it very difficult to organize an orderly portfolio liquidation.

The episode also raised questions about the soundness of the brokers' risk management systems. The brokers lulled themselves into thinking that they were protected because their loans were "fully collateralized." Even so, their loans carried no haircuts and were exposed to the risk that LTCM could default at the same time as the collateral lost value. One of the lessons of this near disaster was to accelerate the integration of credit and market risk management.

13.5 CONCLUSIONS

This chapter has shown how to account for liquidity risk. Traditional VAR models measure the worst change in mark-to-market value over the horizon but do not account for the actual cost of liquidation. These costs depend on the price-impact function, as well as the size of the positions. This leads to a "hybrid" liquidity-adjusted VAR measure that combines price volatility with liquidation costs.

In general, bid-ask spread effects are less important than traditional VAR measures. What matters more are the large price drops owing to liquidating large positions. In normal markets, liquidity effects are fairly predictable. Whether these LVAR measures apply to stressed markets, however, is more doubtful.

An alternative approach is to value positions at the conservative bid-ask quote and even to take a reserve to account for illiquidity. In such cases, there is no need to take liquidity risk into account in VAR because it is already factored into the valuation of positions.

Funding liquidity risk, in contrast, arises when financing for the portfolio cannot be maintained. Here again, VAR can be altered to estimate the risk that a portfolio could run out of cash.

Thus liquidity risk involves the two sides of the balance sheet, assets and liabilities. The greater the liquidation horizon for a portfolio, the greater is the need for extended financing of the portfolio.

The CRMPG recently reviewed the progress made since the original 1999 study in an update dubbed CRMPG II (2005). Many banks have responded that the CRMPG recommendations provided "a useful framework." CRMPG II reports that institutions now have "a greater focus on liquidity-based adjustments to closeout values and on the interaction of asset liquidity and funding liquidity." Still, the CRMPG warns that crises will "inevitably occur" and that "investments in risk management systems should continue to be a high priority."

While LVAR may be somewhat difficult to measure, some rules of thumb are useful. We do know that bid-ask spreads are positively correlated with volatility. A position in illiquid assets will incur greater execution costs as volatility increases. Thus liquidity risk can be mitigated by taking offsetting positions in assets, or businesses, that benefit from increased volatility or have positive vega. Examples are long positions in options and customer trading, which typically benefit when trading volatility and volume spike up.

As with other applications of VAR, the main benefit of this analysis is not so much to come up with one summary risk number but rather to provide a systematic framework for thinking about the interactions among market risk, asset liquidity risk, and funding liquidity risk.

QUESTIONS

1. Define asset and funding liquidity risk.
2. What is a potential problem for the marking-to-market assumption underlying the measurement of VAR if VAR is to measure the worst loss over a liquidation period?
3. Explain how the analysis of market microstructure, or demand and supply curves, is useful to assess liquidity risk.
4. What is the common characteristic of *deep* markets in terms of liquidity risk?
5. Define *normal market sizes*.
6. How is asset liquidity risk controlled?
7. A hedge fund has a position in 1 million shares of a stock whose midprice is $100. The bid-ask spread is $0.40, up to a volume of 100,000. Beyond that, prices fall by $0.50 per share for every 100,000 shares transacted in one day. Compute the loss from the midprice if the entire position is liquidated over 1 day. This should be computed in dollars and in fraction of the initial position value.
8. Repeat with two other scenarios: (a) The sale is spread uniformly over 10 days. (b) The sale is spread over 5 days. Assume that prices are not expected to move.
9. Assuming a daily stock volatility of 1 percent and uncorrelated returns, compute the volatility of holding the original position over 10 days. Then compare the volatility of the three strategies in the previous questions. Ignore intraday risk.
10. What is the tradeoff between liquidating quickly or slowly.
11. Can you explain why hedge funds do not accept new investors after they have reached some size? Would you expect a large or small size for strategies investing in government bonds or high-yield bonds?
12. Some hedge funds have *lockup periods* for their investors, which prevent them from pulling their money within some period. Which type of strategies are more likely to use such clauses: leveraged funds investing in government bonds or high-yield bonds?

13. Explain how funding liquidity risk can arise for leveraged institutions.
14. Do pension funds, which are not leveraged, face funding liquidity risk?
15. Explain what a haircut is (in the context of liquidity risk).
16. Why do companies issue debt with credit triggers? Do you think these are useful features?
17. Among U.S. stocks, bonds, and Treasury bills, which class of assets has the lowest bid-ask spread?
18. What are sources of bid-ask spreads in market microstructure theory?
19. How is the liquidity-adjusted VAR, LVAR, different from the traditional VAR?
20. Is the relative importance of the liquidity term in LVAR greater or smaller as the number of assets increases in a portfolio?
21. What is cash liquidity, as defined by the Counterparty Risk Management Policy Group?
22. What instruments did LTCM use to leverage its balance sheet? Explain.
23. What were the major risks involved in the LTCM debacle?
24. Reviewing the types of trades done by LTCM, do you think this was a well-diversified fund?