8

Arbitrage

This chapter examines the background to and activities of the hedge fund Long-Term Capital Management (LTCM) and the causes of the turmoil that engulfed it in 1998.[1] LTCM was highly skilled: it emerged from the celebrated arbitrage group at Salomon Brothers—a group headed by John Meriwether, widely acknowledged as the most talented bond trader of his generation. LTCM was well versed in finance theory—it was run by, among others, Robert C. Merton and Myron Scholes. It was hugely successful.

Nevertheless, in August and September 1998, in one of the defining moments of the economic history of the 1990s, adverse price movements drove LTCM to the brink of bankruptcy. In the midst of a growing global crisis, it was re-capitalized by a consortium of major banks coordinated by the Federal Reserve Bank of New York.

LTCM practiced arbitrage on an unprecedentedly large scale. Its trading was "arbitrage" in the sense in which the term is used in financial markets: it sought to make low-risk profits by exploiting discrepancies in prices, for example when an unduly large "spread" had opened up between the prices of similar assets.

The "arbitrage" invoked in finance theory differs from LTCM's activities in two respects. First, it demands no capital: it can be performed entirely with borrowed cash and/or borrowed securities. (See, for example, the hypothetical options arbitrage trades in appendix E.) Second, it involves no risk. These are, indeed, precisely the posited features of arbitrage that make its capacity to close price discrepancies unlimited.

LTCM's activities, in contrast, involved risk (even in "normal" times, not just in 1998) and demanded at least modest amounts of capital. Nevertheless, as we shall see, aspects of LTCM's trading were quite close counterparts to some of the classic arbitrages of finance theory.

Bonds, Derivatives, and Arbitrage

The core of the group that formed LTCM came together at Salomon Brothers in the 1980s. Founded in 1910, and for decades excluded from Wall Street's informal "establishment," Salomon developed a reputation for robust competitiveness and for expertise in underwriting and trading in bonds (Sobel 1986). The bonds that governments such as those of the United States, the United Kingdom, France, and Germany issue in their own currencies are regarded as the safest of investments: the chance of default is conventionally regarded as zero.

However, the safety of government bonds does not preclude trading opportunities. Indeed, the U.S. bond markets of the 1980s attracted aggressive traders. The expanding government deficits during the presidency of Ronald Reagan meant that increasing numbers of Treasury bonds had to be issued. Trading volumes increased more than fivefold between 1980 and 1988, to levels in excess of $100 billion a day (Hughes 2004).

Bond prices are related intimately to the level of interest rates. Bonds typically offer fixed "coupons," or interest payments. When interest rates go up, bond prices usually go down (lower prices mean that the "yields" of bonds, the lifetime rates of return they offer at their current market price, go up). If one can predict the future course of interest rates better than others can, one can make money by trading bonds, though in a market like that in U.S. Treasury bonds genuine inefficiencies of this kind appear to be rare.[2]

More subtly, however, anomalies can arise in the pricing of bonds, and these anomalies sometimes become large enough that sophisticated traders can exploit them profitably. For example, the market in newly issued ("on-the-run") U.S. Treasury bonds is more liquid than the market in less recently issued ("off-the-run") bonds: many off-the-run bonds are in the relatively static portfolios of pension funds and insurance companies. Investors concerned with liquidity are therefore prepared to pay a premium for on-the-run bonds.[3]

With the passage of time, however, an on-the-run bond will inevitably become off-the-run, so there may be money to be made by short-selling newly issued bonds and buying their closest off-the-run counterparts. Their yields can be expected to converge, and, crucially, one is insulated from the effects of general rises or falls in interest rates because such changes will affect the prices of both bonds roughly equally.

There is a complex relationship between the yields of bonds and the time remaining to maturity (repayment of the capital sum), a relationship usually summarized by the "yield curve" (figure 8.1). Generally the curve is expected to be reasonably smooth, as in the figure, so if there are "bulges" (for example,

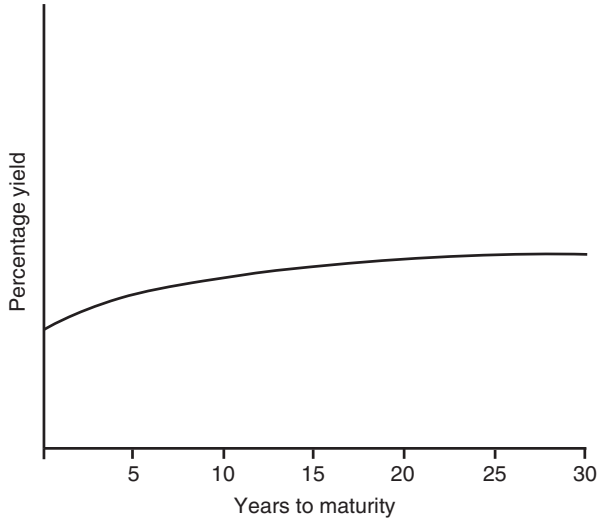

Figure 8.1
A hypothetical example of a yield curve (highly schematic). Yield curves usually (but not always) have the upward slope shown here. Source: MacKenzie 2005. Courtesy of Oxford University Press.

if the yield on bonds with five years to maturity is greater than the yields on either three-year or seven-year bonds) an arbitrage opportunity might again exist.

Adding to the arbitrage opportunities offered by the government bond market are those offered by a variety of closely related markets. One is in mortgage-backed securities. In the United States, in order to improve the supply of mortgage funds, federal agencies provide what market participants often take to be implicit government guarantees for bond-like securities backed by pools of mortgages. The prices of these securities, like those of government bonds, have a tight relationship to interest rate movements, but the holder of a mortgage-backed security has also to consider the risk of mortgage pre-payment, which replaces a stream of future interest payments by a sudden return of the capital lent.

Because of the risk of pre-payment, and because the federal bodies involved are agencies, not the government itself, mortgage-backed securities trade at a discount to (or, to put it in other words, offer higher yields than) government bonds. Typically, the yield of mortgage-backed securities is about one percentage point higher than the yield of government bonds, and there can, for example, be profit opportunities if that difference widens or narrows for temporary reasons.

From the mid 1970s on, the arbitrage opportunities offered by bonds and mortgage-backed securities were expanded by the emergence of markets in derivatives of these securities. The Chicago Board of Trade began trading futures on mortgage-backed securities in October 1975 and futures on U.S. Treasury bonds in August 1977. Markets also began to develop in derivatives (such as bond options and swaps) sold "over the counter"—that is, by direct, institution-to-institution negotiations. (Swaps are contracts to exchange income streams, such as fixed-rate and floating-rate interest on the same notional principal sum.)

The proliferation of bond derivatives offered both greater complexity and new possibilities for profitable trading by those who could grasp that complexity. The focal point of Salomon Brothers' New York headquarters was "The Room," a huge two-level sales and trading floor (Sobel 1986, pp. 116–117, 160–161). It was a tradition at Salomon Brothers that the managing partner (Bill Salomon from 1963 to 1978, John Gutfreund from 1978 to 1991) managed the firm largely from a desk in The Room.

Complementing Salomon's trading focus was a group of researchers who concentrated on the bond market, particularly Sidney Homer (see, e.g., Homer 1978), Henry Kaufman (see, e.g., Kaufman 2000), and Martin Leibowitz (see, e.g., Homer and Leibowitz 1972; Leibowitz 1992). Salomon's tradition was one of "roughneck traders who grew up in the back office, with great instincts" (Meriwether interview), but in the late 1970s and the 1980s there was an increasing emphasis on the recruitment of individuals who combined trading instincts with academic training.

Among the recruits were many of the future principals of LTCM: first John Meriwether, then Larry Hilibrand, Richard Leahy, Victor Haghani, Eric Rosenfeld, Greg Hawkins, and Bill Krasker. At first Meriwether and his colleagues (many of whom Meriwether had hired) focused on simple arbitrage trades, such as on-the-run/off-the-run, but increasingly they performed more complicated trades that required not only the instincts of a "roughneck" trader but also mathematical sophistication.

To identify arbitrage opportunities involving mortgage-backed securities, for example, one has to examine the extent of the "spread" of their yields over government bonds after taking into account the mortgage holders' prepayment option. It is also necessary to work out how to hedge the pre-payment risk, for instance by purchasing interest-rate options.

The growing complexity of arbitrage led to an increasing connection between Salomon's proprietary trading and finance theory. Bonds are more complicated than stocks from the viewpoint of mathematical modeling. There is no single dominant model of interest-rate fluctuations equivalent to the

log-normal random walk for stocks. The value of a bond at maturity is a deterministically fixed, not a stochastic, sum of money, and yield curves are both complex and subject to radical changes in shape. Nevertheless, while the financial economics of the markets in bonds and bond derivatives did not achieve the canonical status of the stock and stock-derivative models discussed in earlier chapters, in the 1970s theoretical progress began to be made in the modeling of bond prices.[4]

As bond derivatives developed beyond bond futures to encompass a variety of bond options, the skills of those trained in finance theory became an increasingly important source of competitive advantage for Salomon Brothers. However, it is important not to overstate the sophistication of the application of theory or the criticality of particular models, as popular accounts of the Salomon/LTCM group (Dunbar 2000; Lowenstein 2000) do. In 1984, for example, Meriwether recruited to Salomon Eric Rosenfeld, an assistant professor at the Harvard Business School whose Ph.D. work had been supervised by Robert C. Merton. In addition to his arbitrage trading between the market in bonds and the market in bond futures, Rosenfeld helped a group selling bond options to design and to price their products.

Rosenfeld developed straightforward empirical models of the yield curve, and he priced bond options simply by assuming that the probability distribution of the price of the bond at the expiry of the option was log-normal. "Sometimes," he recalls, "we'd assume normal just to make it even more simple." Rosenfeld's academic work had been much more sophisticated, but there would have been little point in carrying over this sophistication. "We used so much simpler models than I had been used to," he says. ". . . And . . . I don't think it mattered. We weren't out in a region where the particular specification of the model mattered." (Rosenfeld interview)

At first the arbitrage activities of the Salomon group had focused exclusively on the United States. But as other countries also began to deregulate their financial systems, arbitrage opportunities began to appear in capital markets overseas. Japan, for example, partially liberalized its financial system in the 1980s, and Salomon became heavily involved in arbitrage involving convertible bonds. (A convertible bond is one that includes an option to exchange it for another asset, in most cases for stock of the corporation that has issued it. Often such bonds trade at prices different from those implied by the value of the option as calculated by Black-Scholes or other models of option pricing.) The bank made almost $1 billion in two years of arbitrage trading of this kind in Japan (Meriwether interview).

As time passed, large and obvious arbitrage opportunities diminished, first in the United States and then elsewhere. By 1986, realizing the need for greater

sophistication in order to keep ahead of his competitors, Meriwether had developed "a pronounced game plan to interact with academia," indeed to "evolve into a quasi-university environment" (Meriwether interview). He sent Salomon employees to visit universities and to attend the conferences of the American Finance Association. By the late 1980s, Eric Rosenfeld and his colleagues were no longer modeling the yield curve by empirical curve fitting; they were using the more sophisticated models that had begun to appear in the academic literature (Rosenfeld interview).

However, the use of mathematical models by Meriwether's group played only a limited part in his growing reputation as the best bond trader of the period. At least equally important was his understanding of the institutional structure of the bond market: its "embedding," as the Granovetterian tradition in economic sociology would put it (Granovetter 1985). A successful arbitrage trader had to attend not only to mathematical models but also to the institutional determinants of supply and demand for bonds: who held which bonds and why, which bonds were readily available and which might suddenly be in short supply, and so on. The mere existence of a price discrepancy was not sufficient to persuade Meriwether to put a trade on: he had to feel satisfied that he knew *why* the discrepancy existed. Among the reasons this kind of institutional understanding was necessary was the possibility of a "short squeeze," which, though only occasionally the result of deliberate action, is in some ways reminiscent of the grain "corners" described in chapter 1. Typically, one leg of a bond arbitrage trade is constructed by short-selling a particular class of bonds (often government bonds of long maturity). Especially if others have the same or similar trades on, maintaining the ability to borrow the requisite bonds can become difficult and expensive,[5] wiping out the profit from the trade and possibly forcing it to be liquidated at a loss. Such "squeezability" might not appear as a feature of mathematical models, but was an ever-present risk of which bond-market arbitrageurs had to be aware. "Mathematics was helpful," says Meriwether, but the kind of understanding of the institutional structure of the market that comes only from experience was—precisely as the Granovetterian tradition would predict—"more important" (Meriwether interview).

As important as understanding the risks arising from the institutional structure of the bond market were financing and obtaining the necessary positions. Arbitrage trading involves trying to profit from pricing discrepancies that often correspond to a difference in yields between similar assets of a fraction of a percentage point. For example, in the 1990s the difference in yields between the on-the-run and the most recent off-the-run 30-year U.S. Treasury bonds was seldom much more than a tenth of a percentage point, and often much

less (Krishnamurthy 2002, p. 465, figure 2). Arbitrage trading therefore inherently involves leverage: the use of borrowed capital to increase rates of return to the point at which they become attractive.

The capacity to borrow money in order to buy securities is thus critical to the practical conduct of arbitrage. (Borrowing is also an essential feature of finance-theory models that invoke arbitrage. As was noted above, it allows the latter to be modeled as demanding no capital.) In bond trading, the most important form of leverage is "repo," a way of borrowing money to buy securities such as bonds and using those securities as collateral for the loan. (See appendix F.)

In Rosenfeld's judgment, "a major thing that John [Meriwether] did was making [repo] an integral part of our business" (Rosenfeld interview). It was critical to know what could be "repoed" and on what terms. Typically, lenders do not lend the full price of the securities being repoed; they impose a "haircut" to protect themselves against the risk of borrowers defaulting in a situation in which the market value of the loan's collateral has fallen. In the U.S. government bond market, "haircuts" usually are modest (around 2 percent), but they can be larger for other securities, and in critical situations they can increase sharply.

Repo, Rosenfeld recalls, was not a prominent or a prestigious business: "In the 1970s and 1980s, it wasn't done by the top people at the firm; it was . . . almost like a clerk's job." Rosenfeld and his Salomon colleagues "always spent a lot of time with those guys and that was very important to us." Equally important was discovering what bonds could be borrowed for short sale, and on what terms. The members of Meriwether's group kept in close contact with others at Salomon who knew "if they had any bonds that . . . looked like they were going to be there for a long time that we could borrow. And then we'd sell them and buy the cheap assets against it." (Rosenfeld interview)

As Salomon's arbitrage activities began to expand overseas, Meriwether—who, like the traders at Dimensional Fund Advisors, was a good practical economic sociologist—realized that it would not be enough simply to send Americans, however sophisticated mathematically, into overseas markets. "Knowing the culture," he says, "was more important than just quantitative knowledge." (Meriwether interview)

Typically, Salomon would seek to recruit people who had been brought up overseas, train them in New York, and then send them back to the markets in the countries in which they had been brought up. The head of Salomon's trading activities in Japan, the legendarily successful Shigeru Miyojin, is an instance. Someone who was not fluent in Japanese would be at a disadvantage, and in Japan (as elsewhere) the price discrepancies that were of interest

to arbitrage would typically be "driven by the tax and regulatory framework." An outsider would often find that framework hard to comprehend in sufficient depth (Meriwether interview).

Long-Term Capital Management

LTCM, which began trading in February 1994, was based in Greenwich, Connecticut. It also had an office in London and a branch in Tokyo. Its primary registration—like that of many other hedge funds—was in the Cayman Islands.

LTCM's offices were not ostentatious (its Greenwich head office, for example, was a modest, low-rise suburban office block), and the partnership was not large (initially, 11 partners and 30 employees; by September 1997, 15 partners and about 150 employees). These people, however, managed considerable assets: in August 1997, $126 billion, of which $6.7 billion was the fund's own capital. Whereas most hedge funds cater to wealthy individuals, such individuals were the source of less than 4 percent of LTCM's capital, which came mostly from financial institutions, particularly banks (Perold 1999, pp. A2, A22).

LTCM's basic strategy was "convergence" and "relative-value" arbitrage: the exploitation of price differences that must be temporary or that have a high probability of being temporary. Typical were its many trades involving "swaps." By the time of LTCM's crisis, its swap book consisted of some 10,000 swaps with a total notional value of $1.25 trillion.[6]

As has already been noted, a swap is a contract to exchange two income streams—for example, fixed-rate and floating-rate interest on the same notional sum. Swaps are a recent invention—they date only from the early 1980s—but they have become important financial derivatives, widely used to manage the risks of interest-rate fluctuations. Around 47 percent of the $273 trillion in total notional amounts of derivatives contracts outstanding worldwide at the end of June 2004 was made up of interest-rate swaps.[7]

The "swap spread" is the difference between the fixed interest rate at which swaps can be entered into and the yield of a government bond with a similar maturity denominated in the same currency. Swap spreads can indicate arbitrage opportunities because the party to a swap who is paying a floating rate of interest while receiving a fixed rate is in a situation similar to that of someone who has borrowed money at a floating rate and used it to buy a bond that pays fixed interest. If there is enough of a discrepancy between the terms on which swap contracts can be entered into and on which positions in bonds in the same currency and of similar maturities can be financed, arbitrage may be possible. (A typical LTCM swap-spread arbitrage is described in appendix G.)

Several features of swap-spread arbitrage are typical of LTCM's trading. The first is leverage. LTCM's swap-spread trades were highly leveraged—that is, they were constructed largely with borrowed capital. In the trade discussed in appendix G, LTCM's position amounted to $5 billion. The capital required by LTCM to construct this position was, however, only around $100–$125 million: a "haircut" of around $50 million, and $50–$75 million for "risk capital" (provision for adverse price movements). The leverage ratio of the trade—the ratio of the total position to the amount of LTCM's own capital devoted to the trade—was thus in the range from 40:1 to 50:1. While not all the fund's positions were as highly leveraged as that, its overall leverage ratio between June 1994 and December 1997 fluctuated between 14:1 and 31:1 (Perold 1999, pp. A22, C12).

High levels of leverage, however, did not necessarily imply huge risk (as much subsequent commentary suggested). For example, the risks of swap-spread trades are rather limited. Bond prices and the terms on which swaps are offered fluctuate considerably, particularly as interest rates vary. LTCM, however, almost always neutralized that risk by constructing "two-legged" trades, in which the effects on one "leg" of a change in interest rates would be canceled by its equal-but-opposite effect on the other "leg." (The trade in appendix G is an example.) The chief "market risk" of swap-spread trading is of the spread temporarily moving in an unfavorable direction, but if that happens the arbitrageur can simply continue to hold the position and wait until liquidating it becomes profitable.

Indeed, a swap-spread position such as that described in appendix G can be held until the bond matures and the swap expires. That feature was taken to be the essence of convergence arbitrage: if held to maturity, a convergence arbitrage position *has* to make a profit, whatever the market's fluctuations along the way.

Any "credit risk" (risk of default) associated with swap-spread arbitrage like the trade in appendix G is typically small. The risk of the U.S. government's defaulting on its bonds is regarded as negligible; bond futures contracts are guaranteed by the clearinghouse of a derivatives exchange such as the Chicago Board of Trade; and LTCM's swap contracts were typically with major banks. Even major banks may fail, but because the principal sum in a swap is not exchanged, it is only notional and is at no risk: the credit risk involved is only of the loss of future net differences between fixed-rate and floating-rate interest.

Although the risks were limited, the profits from LTCM's swap-spread trading were impressive. The trade described in appendix G earned a profit of $35 million, which was a return of 28–35 percent achieved in eight months or less. Nor was this untypical. Between February and December 1994,

LTCM's returns before fees were 28.1 percent (un-annualized); after management and incentive fees were deducted, investors received 19.9 percent (un-annualized). Gross returns in 1995 were 59.0 percent, and returns after fees 42.8 percent; in 1996, the corresponding percentages were 61.5 and 40.8.[8]

Although LTCM was active in the American and Japanese markets, it had particularly heavy involvement in European markets. In the 1990s, financial deregulation in Europe proceeded apace, but arbitrageurs such as LTCM initially found much less competition than in the United States or Japan. "The Japanese banks," according to Costas Kaplanis (who in 1998 was Salomon Brothers' head of global arbitrage), "were the ones who were terribly interested in setting up proprietary [trading] desks. The European banks were still a bit hesitant." (Kaplanis interview)[9]

LTCM scrutinized the "yield curves" for European government bonds and the corresponding swap curves, looking for the "bulges" and other anomalies that might indicate arbitrage opportunities. If LTCM was confident that it understood the reasons for anomalies (often they were matters such as regulatory requirements that caused insurance companies to hold bonds of particular maturities), it would seek to exploit them by trades carefully constructed to neutralize the risks of interest-rate fluctuations or of changes in the overall steepness of the yield curve.

For example, LTCM became heavily involved in the Italian capital markets, which in the late 1990s became a particularly important site of trading, not only by LTCM but also by leading U.S. investment banks. Traditionally, the fiscal efficiency of the Italian state was regarded as poor by international (and many local) investors, who would therefore purchase Italian government bonds only at low prices, and thus at high yields. Until 1995, a 12.5 percent withholding tax on bond coupon payments added to the unattractiveness to international investors of Italian bonds. The tax was refundable, but getting it refunded took time and "back-office capability" (Muehring 1996, pp. 72–73).

The high yields of Italian government bonds contributed to Italy's budgetary difficulties by making the cost of servicing its government debt high. However, with growing European integration, and especially with the prospect of economic and monetary union, arbitrageurs began to believe that Italy's capital-market idiosyncrasies might be temporary. This belief may have been self-fulfilling, in that the resultant flow of capital into Italian government bonds, and the consequent reduction of debt-service costs, helped Italy qualify for monetary union under the Maastricht criteria.[10]

Besides diversifying geographically, LTCM diversified from bonds, bond derivatives, and interest-rate swaps into other asset classes. Some of its relative-value trades involved pairs of stocks, such as Royal Dutch and Shell

Transport. Until 2005, Royal Dutch stocks were traded in Amsterdam and the corresponding American Depository Receipts were traded in New York, while Shell stocks were traded in London, but the 1907 agreement that created the Royal Dutch/Shell group made the two sets of stocks equivalent entitlements to the income of what was essentially a single entity.[11] The Royal Dutch/Shell group's net income was simply split in a fixed ratio between its two component companies. Nevertheless, the actual ratio of the price of Royal Dutch stock to that of Shell stock was often not the ratio implied by this split. Two sets of stocks that were rights to equivalent income streams were thus trading at inconsistent prices, for reasons that seem to have to do with matters such as the different ways in which dividends paid to different categories of investor were taxed (Froot and Dabora 1999).

When LTCM took a position in Royal Dutch and Shell stocks, the discrepancy in the prices was not big enough, if it remained unchanged, for an arbitrageur to profit simply by holding a short position in the more expensive stock (Royal Dutch) and an equivalent long position in the cheaper one (Shell). The "dividend pickup" income from doing that was more than canceled by the costs of financing the position. However, LTCM believed that forthcoming changes in U.K. tax law would remove much of the reason for the lower relative price of Shell stock (Perold 1999, p. A9). By taking the matched short and long positions, LTCM therefore expected to profit from an expected change in relative value while being protected from overall stock-market fluctuations, from industry-specific factors such as the price of oil, and even from the performance of Royal Dutch/Shell itself.

Another stock-related position, taken on by LTCM in 1997, responded to an anomaly that was developing in the market for stock-index options with long expirations. Increasingly, banks and other financial companies were selling investors products with returns linked to gains in stock indices but also with a guaranteed "floor" to losses. Long-maturity options were attractive to the vendors of such products as a means of hedging their risk, but such options were in short supply. The price of an option is dependent on predictions of the volatility of the underlying asset, and market expectations of that volatility ("implied volatility") can be deduced from option prices using option theory.

In 1997, the demand for long-expiry options had pushed the volatilities implied by their prices to levels that seemed to bear little relation to the volatilities of the underlying indices. Five-year options on the S&P 500 index, for example, were trading at implied volatilities of 20 percent per year and higher, when the volatility of the index itself had for several years fluctuated between 10 percent and 13 percent, and the implied volatilities of shorter-term options were also much less than 20 percent per year. LTCM therefore sold large

quantities of five-year index options, while hedging the risks involved with index futures and sometimes also with short-expiry options (Perold 1999, pp. A7–A8).

Not all of LTCM's trades were successful. For example, Eric Rosenfeld recalls that LTCM "lost a lot of money in France in the front end [of the bond yield curve]" (Rosenfeld interview). Nevertheless, extremely attractive overall returns were earned, and the volatility of those returns was reassuringly low. Most of LTCM's positions were almost completely insulated from overall increases or decreases in the prices of stocks or bonds. The firm had only limited involvement in areas where the chance of default was high, such as "junk bonds" (lower-than-investment-grade corporate bonds) and "emerging markets" (e.g., Russia, Thailand, Argentina).

The risks involved in LTCM's positions were carefully calculated and controlled using the "value-at-risk" approach, a standard practice of the world's leading banks (Meriwether interview). Value-at-risk is a measure of the exposure of a portfolio to adverse price movements. In the case of the dollar swap spread, for example, historical statistics and judgments of likely future values led LTCM to estimate that the spread had an "equilibrium value" of around 30 basis points, with a standard deviation of about 15 basis points per annum (Rosenfeld interview; a "basis point" is a hundredth of a percentage point). Using those estimates, it was then possible to work out the relationship between the magnitude of possible losses and their probabilities, and thus to work out the value-at-risk in the trade.

When a trading firm holds a large number of positions, the estimation of the probabilities of loss in individual positions is less critical to overall value-at-risk than estimates of the correlations between positions. If correlations are low, a large loss in one position is unlikely to be accompanied by large losses in others, so aggregate value-at-risk levels will be modest. In contrast, if correlations are high, then when one position "goes bad," it is likely that other positions will also do so, and overall value-at-risk will be high.

LTCM's positions were geographically dispersed, and in instruments of very different kinds. (See table 8.3 below for an example of the typical range of its major positions.) At the level of economic fundamentals, little if anything connected the spread between U.S. government bonds and mortgage-backed securities to the difference between the prices of the stock of pairs of companies such as Royal Dutch and Shell, the idiosyncrasies of the Italian bond market, the bulges in the yen yield curve, or the chances of specific mergers' failing. LTCM was aware that its own and other arbitrageurs' involvement in these diverse positions would induce some correlation, but nevertheless the observed correlations, based on five years' data, were very small—typically 0.1 or lower.

The standard deviations and correlations that went into LTCM's aggregate-risk model were, however, not simply the empirically observed numbers; they were deliberately conservative estimates of future values. The observed standard deviation of the U.S. dollar swap spread, for example, was around 12 basis points a year, while, as noted above, the risk model assumed it would be 15 (Rosenfeld interview). Past correlation levels, likewise, were "upped" to provide a safety factor: despite observed correlations being 0.1 or less, LTCM was "running analyses at correlations at around 0.3" (Meriwether interview).

The consequence of conservatism in LTCM's modeling was that while the firm's risk model suggested that the annual volatility of its net asset value would be 14.5 percent, in actuality it was only 11 percent (Meriwether interview). Both of these percentages were considerably lower than the risk level—20 percent—that investors had been told to expect (Perold 1999, p. A11).

Of course, such statistical analyses of risk assumed the absence of catastrophic events in the financial markets. The partners in and several of the employees of LTCM had reason to be aware of the possibility of such events. David W. Mullins Jr., who joined LTCM after serving as Vice Chairman of the Federal Reserve and as Assistant Secretary of the Treasury, had been Associate Director of a presidential task force that had produced a report on the 1987 stock-market crash (Brady Commission 1988). Gérard Gennotte had co-authored the analysis of the crash (Gennotte and Leland 1990) mentioned in chapter 7, and Meriwether and his colleagues at Salomon had been heavily involved in trading at that time. LTCM was born into the midst of the bond market turmoil of 1994, when sharp interest-rate increases after a period of relative stability caused large losses to many investors (including the bankruptcy of Orange County, California, which had taken large, unhedged positions in interest-rate derivatives).

So LTCM also "stress tested" its portfolio, investigating the consequences of hypothetical events too extreme to be captured by statistical value-at-risk models—events such as a huge stock-market crash, a bond default by the Italian government, devaluation by China, or (particularly salient in view of LTCM's European involvement) a failure of European economic and monetary union. In addition to investigating the consequences of such events for market prices and for LTCM's risk capital, LTCM calculated—and set aside—the funds necessary to cope with a sudden increase in "haircuts" in a situation of stress. When an event could have particularly catastrophic consequences, LTCM either turned to insurance (it bought what was in effect insurance against bond default by the government of Italy) or balanced its portfolio to minimize consequences (as in the case of failure of European monetary union).

Was LCTM's Trading Arbitrage?

Clearly, LTCM's trading involved risk. It is therefore, tempting to conclude that what LTCM did—although it was unquestionably "arbitrage" in financial-market usage of the term—was not arbitrage as it is conceived within finance theory. However, LTCM's index option positions were quite close to the arbitrage that finance theory posits as imposing Black-Scholes option pricing. LTCM sold index options and hedged them by constructing a "replicating portfolio," although the detail of the construction of the latter was more complex than in the textbook case, and the model of stock-price changes that LTCM used was a "proprietary" one, not the log-normal random walk of the Black-Scholes-Merton model (Perold 1999, p. A8).

More generally, beginning with the work of Modigliani and Miller, it was fundamental to finance theory that, in the words of Myron Scholes, "the market will price assets such that the expected rates of return on assets of similar risk are equal." If the market did not do so, Modigliani, Miller, and their successors reasoned, "investors seeing these profit opportunities would soon arbitrage them away" (Scholes 1972, p. 182). LTCM's "relative value" arbitrage can be seen as precisely this kind of arbitrage.

Of course, just what count as assets of "similar risk" is potentially contentious. The practice of arbitrage can, indeed, be seen as hinging on the identification of similarity that is "good enough" for practical purposes—see the work of Beunza and Stark (for example, Beunza and Stark 2004), which will be discussed in chapter 9—and the issues involved are deep: judgments of similarity are basic to the application of concepts (Barnes, Bloor, and Henry 1996).

Nevertheless, consider LTCM's Royal Dutch/Shell arbitrage, described above. The Royal Dutch/Shell group's net cash flow was split on a fixed 60:40 basis between Royal Dutch and Shell (Froot and Dabora 1999, p. 192). Royal Dutch stocks and Shell stocks were thus claims on two future income streams that were identical (the 60:40 constant of proportionality aside), in that they arose from dividing a single income stream in a set ratio. (In Modigliani and Miller's terms, the two sets of stocks were thus in the same "risk class."[12])

It would therefore seem not unreasonable for market participants to regard Royal Dutch stocks and Shell stocks as "assets of similar risk" in respect to cash flows. It is indeed a case in which "in a frictionless world, it is clear that arbitrage would occur [and] drive prices to parity" (Froot and Dabora 1999, p. 215). Such cases are close enough to the "arbitrage" posited by finance theory to be of interest.

The Crisis of 1998

LTCM's crisis provoked widespread comment—for example, books by Dunbar (2000) and Lowenstein (2000)—and even featured in a novel (Jennings 2002). Typically, popular commentary advanced two accounts:

(1) The partners in LTCM were guilty of greed and gambling (consciously reckless risk-taking).

(2) LTCM had blind faith in the accuracy of finance theory's mathematical models.

More informed discussion (for example by the President's Working Group on Financial Markets 1999) avoided blaming individuals' alleged character flaws, and instead advanced a third hypothesis:

(3) LTCM was over-leveraged—too high a proportion of its positions was financed by borrowing, rather than by LTCM's own capital.

This third hypothesis, however, explains at most LTCM's vulnerability to the events of August and September 1998: it does not explain those events. The most common explanation of them is as follows:

(4) On August 17, 1998, Russia defaulted on its ruble-denominated bonds and devalued the ruble. This triggered a "flight to quality" in the financial markets—a sudden greatly increased preference for financial assets that were safer (less prone to default) and more liquid (more readily bought and sold).

That there was a flight to quality in August and September 1998, and that the Russian default triggered it, cannot be denied. The hypothesis of this chapter, however, is that superimposed on the flight to quality, and sometimes cutting against it, was a process of a different, more directly sociological kind:

(5) LTCM's success led to widespread imitation, and the imitation led to a "superportfolio" of partially overlapping arbitrage positions. Sales by some holders of the superportfolio moved prices against others, leading to a cascade of self-reinforcing adverse price movements.

The first explanation—consciously reckless risk-taking—is entirely inadequate as an account for LTCM's 1998 disaster. The partners in LTCM believed themselves to be running the fund conservatively, and in the modest volatility of its returns they had evidence for the correctness of this belief. After the fund's crisis, it was commonly portrayed as wildly risk-taking, but it is hard to

find anyone inside or outside LTCM who can be proved to have expressed that view before the crisis.[13]

Nor does the second hypothesis advanced in the commentary—blind faith in mathematical models—explain the crisis. Models were much less critical to LTCM's trading than commonly thought. Many of the pricing anomalies it sought to exploit (such as the premium of shares in Royal Dutch over those in Shell, or the swap-spread example discussed in appendix G) could be identified without sophisticated modeling. Although models were important to how LTCM's trades were implemented and to assessing the risks involved, all those involved knew that models were approximations to reality and a guide to strategy rather than a determinant of it.

LTCM's traders had often themselves developed the models they used: no one was more aware than they of the models' likely deficiencies. The way in which the standard deviations and correlations in the most important model of all—LTCM's overall risk model—were increased by explicitly judgment-based "safety factors" is indicative of that.

The third posited explanation of LTCM's crisis—over-leverage—is almost tautologically correct. If LTCM had been operating without leverage, or at low levels of leverage, the events of August and September 1998 would have placed it under much less strain. However, leverage was intrinsic to the kind of arbitrage performed by LTCM. As can be seen in the example in appendix G, unleveraged rates of return are typically paltry. Only with leverage does arbitrage of the kind conducted by LTCM become attractive.

LTCM's pre-crisis leverage ratios were not, in fact, egregious when compared, for example, to those of investment banks. In the early months of 1998, LTCM's leverage ratio was around 27:1 (Perold 1999, pp. C11–C12). 27:1 was the *average* ratio of the five biggest investment banks at the end of 1998 (President's Working Group on Financial Markets 1999, p. 29).

Blaming LTCM's crisis on leverage is similar to attributing a plane crash to the fact that the aircraft was no longer safely in contact with the ground: it identifies the source of overall vulnerability but not the specific cause. That cause was the financial crisis of August and September 1998, and in particular the way in which the adverse price movements of those months exceeded LTCM's, or anyone else's, expectations. As noted above, the 1998 crisis involved an increased relative preference for safer, more liquid assets.[14] Since many of LTCM's (and other arbitrageurs') trades involved short-selling such assets while having a "long" position in their less creditworthy or less liquid counterparts, this shift in preferences altered prices in a way that caused losses to LTCM and to other arbitrageurs (albeit losses that in many cases one could be confident would be recouped).

However, the interviews drawn on here suggest that overlaying the increased preference for safer, more liquid assets were the effects of a different, more directly sociological process. Meriwether's group at Salomon and at LTCM earned remarkable profits, and were *known* to have earned those profits. This had encouraged others—in other investment banks, and increasingly in other hedge funds—to follow similar strategies.

Meriwether's group had been imitated even in its days at Salomon Brothers. In the market for mortgage-backed securities, a crucial issue, as noted above, is calculating the impact of homeowners' "pre-payment" option. The calculation was a non-trivial modeling task that typically took the form of adjusting the "spread" of the yield of mortgage-backed bonds over the yield of Treasury bonds of similar maturities to take the pre-payment option into account.

From 1985 to 1987, Richard Roll was head of mortgage securities research for Goldman Sachs, and was well placed to observe behavior in the market for such securities. "The people making more money," he says, "were the ones with the better models, the Meriwethers of the world." Those who were less sophisticated in their modeling learned from the Salomon group by what Roll calls "mimicry": by inferring from Salomon's trading the features its model must have. Roll puts it this way: "If you saw Meriwether going long [that is, buying a mortgage-backed bond] with an option-adjusted spread you thought was five basis points, you knew that *his* model said it's 100 basis points." In consequence, less experienced participants in the market would ask themselves what they would have to do to *their* pre-payment model to generate a larger spread, saying to themselves, in Roll's words, "Let's tinker with [the model] and see if we can get that." (Roll interview)

Imitation seems to have intensified after LTCM's success became public. Other traders were being told "LTCM made $2 billion last year. Can't you?" (Meriwether interview). For example, LTCM's success meant that it rapidly became largely closed to new investors, and in January 1998 a new fund, Convergence Asset Management, "raised $700 million in a single month purely from disgruntled investors denied a chance to buy into LTCM" (Dunbar 2000, p. 197).

LTCM tried hard not to reveal its trading positions. For example, it would avoid using the same counterparty for both "legs" of an arbitrage trade. However, as one trader and manager not connected to LTCM put it, "the arbitrage community . . . are quite a bright lot, so if they see a trade happening—and the market gets to find out about these trades, even if you're as secretive as Long-Term Capital Management—they'll analyze them and realize there's an opportunity for themselves" (Wenman interview).

Even if the details of LTCM's trading could not be discovered, its basic strategy—convergence and relative-value arbitrage—had to be disclosed to potential investors, and others seeking to follow that strategy would often be led to take positions similar to LTCM's. It "[didn't] take a rocket scientist" to discover the kinds of arbitrage opportunities being pursued by LTCM (Rosenfeld interview), especially when discovering one leg of an LTCM trade through being a counterparty to it would greatly narrow the range of likely other legs.

Some of LTCM's trades were well known to market insiders before LTCM became involved. The Royal Dutch/Shell trade, for example, was the "classic European arbitrage trade" (Wenman interview), and the relationship between Royal Dutch and Shell shares had even been discussed in the academic literature before LTCM was founded (Rosenthal and Young 1990). News or speculation about other LTCM trades circulated freely. "I can't believe how many times I was told to do a trade because the boys at Long-Term deemed it a winner," says the hedge-fund manager James Cramer (2002, p. 179).

As a result of conscious and unconscious imitation, many of LTCM's positions became, in the words of an arbitrageur who was not affiliated to LTCM, "consensus trades" (Kaplanis interview). Of course, the growing number of arbitrage traders in investment banks and hedge funds did not sit down together in a room to identify good arbitrage opportunities. Rather, "the arbitrage philosophy . . . had been disseminated, well disseminated by August '98; it was there in quite a few hedge funds, it was there in quite a few firms. So Salomon [and LTCM] lost their uniqueness in doing these things. There were many, many others that could do them." (Kaplanis interview)

There was *some* communication: "If you talk[ed] to another arb trader in the street, they'd say 'Oh yes, I have this as well, I have that as well.'" (Kaplanis interview) But even had there not been communication, many traders would still have identified the same opportunities. "And what happened by September '98 is that there was a bunch of arb trades that . . . became consensus. People knew that the U.K. swap spreads was a good trade, people knew that U.S. swap spreads was a good trade." (Kaplanis interview) No other market participant would have had the same portfolio as LTCM did—many arbitrageurs were restricted organizationally or by limited expertise to particular portions of the spectrum of arbitrage trades—but, collectively, much of LTCM's portfolio of positions was also being held by others.

The initial effect of imitation was probably to LTCM's benefit. If others are also buying an "underpriced" asset and short-selling an "overpriced" one, the effect may be to cause prices to converge more rapidly. However, as Eric Rosenfeld of LTCM indicated to me in interview, the growing presence of

other arbitrageurs also meant that when existing trades *had* been liquidated profitably, replacing them was more difficult:

MacKenzie: Did you find that, as the years went by with LTCM—'94, '95, '96, '97, and so on—did you find . . . that the opportunities were drying up a bit?

Rosenfeld: Yes, big.

In the summer of 1998, imitation switched to become a disastrously negative factor because of two decisions, neither of which had anything directly to do with LTCM. In 1997, Salomon Brothers had been taken over by the Travelers Corporation, whose chairman, Sanford I. Weill, was building the world's largest financial conglomerate, Citigroup (Booth 1998). According to Kaplanis, Salomon's U.S. arbitrage desk had not consistently been successful since the departure of Meriwether and his group, and in the first half of 1998 it was loss making: by June, "U.S. was down about 200 [million dollars]. . . . So Sandy [Weill] . . . closed it [Salomon's U.S. arbitrage desk] down" (Kaplanis interview). The closing of the desk was announced on July 7.

Though Kaplanis, promoted to head of global arbitrage for Salomon, advised against it, the decision was taken to liquidate the U.S. arbitrage desk's portfolio as quickly as possible, and responsibility for the liquidation was passed to Salomon's U.S. customer desk. Since the latter was "not accountable for the losses generated as a result of the liquidation, the speed of the latter was faster than would otherwise have been the case." This caused losses not just to Travelers/Citicorp but also to all of those who had similar positions: "Not only did we lose money as the positions went against us as we were selling them, but all the other funds that also had these consensus trades also started losing money." (Kaplanis interview)

If the liquidation of Salomon's arbitrage positions was a background factor in the problems of the summer of 1998, the immediate cause of the 1998 crisis was, as noted above, Russia's August 17 default on its ruble-denominated debt. That Russia was in economic trouble was no surprise: what was shocking was that it (unlike previous debtor governments) should default on debt denominated in domestic currency.

"I was expecting them [the Russian government] to just print money" to meet their ruble obligations, says Kaplanis (interview), and he was not alone in this expectation. True, some investors in ruble-denominated bonds had hedged against the risk of Russia defaulting by short-selling Russian hard-currency bonds (Shleifer 2000, p. 108). For those investors, however, even the good news of August 17—Russia's avoidance of a hard-currency default—was damaging, because it meant their hedge failed to protect them to the extent it should have.

Initially, the Russian default seemed to some to be an event of only modest significance. Robert Strong of the Chase Manhattan Bank told analysts that he did "not view Russia as a major issue" for the banking sector. Investors more generally seemed to share his viewpoint: on August 17, the Dow Jones Industrial Average rose nearly 150 points (Lowenstein 2000, p. 144).

In the days that followed, however, it became increasingly clear that Russia's default had triggered what Kaplanis calls an "avalanche." The default was combined with a de facto devaluation of the ruble of 25 percent and a three-month moratorium on the "foreign obligations" of Russian banks (Marshall 2001, p. 4). Since Western investors used foreign-exchange forward contracts with these banks to hedge against the declining value of the ruble, widespread losses were incurred.

LTCM itself had limited exposure to the Russian market, and suffered only modest losses, but Credit Suisse, for example, incurred losses of about $1.3 billion. Arbitrageurs carrying losses incurred in Russia began liquidating other positions to meet the demands of their counterparties. A hedge fund called High-Risk Opportunities, which had a large position in ruble-denominated bonds, was forced into bankruptcy, owing large sums to Bankers Trust, Credit Suisse, and the investment bank Lehman Brothers. Rumors began to circulate that Lehman itself faced bankruptcy. For weeks, Lehman "went bankrupt every Friday" according to the rumor mill. Though the bank survived, its stock price suffered badly.

In a situation in which the failure of a major investment bank was conceivable, there was indeed a "flight to quality," an increased preference for safe, liquid assets. In August and September 1998, the prices of such assets rose sharply relative to the prices of their less safe or less liquid counterparts. By September 18, the on-the-run "long bond"—the 30-year maturity U.S. Treasury bond—had risen in price to such an extent that its yield was lower than for three decades (President's Working Group on Financial Markets 1999, p. 21). As noted above, the consequence of the flight to quality triggered by the Russian default was, therefore, a shift in prices the typical effect of which was to cause losses to convergence and relative-value arbitrageurs.

LTCM had known perfectly well that a flight to quality could happen and that this would be its consequence. Indeed, it was of the very essence of convergence and relative-value arbitrage that spreads could widen—relative prices could move against the arbitrageur—before a trade finally converged. For that reason, LTCM had required investors to leave their capital in the fund for a minimum of three years: it was in part this restriction that made the fund *Long-Term* Capital Management.[15]

If spreads widened, however, it was assumed within LTCM that arbitrage capital would move in to exploit them, and in so doing restrict the widening (Rosenfeld interview). Indeed, once spreads had become wide enough, it was expected that purchases by ordinary investors, attracted by the increased relative returns of unfavored assets, would reduce them.

The configuration of the markets by August 1998, however, was that the widening of spreads was self-feeding rather than self-limiting. As arbitrageurs began to incur losses, they almost all seem to have reacted by seeking to reduce their positions, and in so doing they intensified the price pressure that had caused them to make the reductions.[16] In some cases, senior management simply became "queasy" (Rosenfeld interview) at the losses that were being incurred, and unwilling to incur the risk of further, possibly larger, losses before trades turned profitable. In the United Kingdom, for example, Salomon, LTCM, a large British bank, and others had all taken positions in the expectation of a narrowing of sterling swap spreads. As those spreads widened, the senior management of the British bank decided to exit:

> [The bank] of course never had a tradition of risk taking. [It] is a household conservative name. So they were the first . . . to start getting out of positions in [the] U.K. swap spread; that hurt us [Salomon], LTCM as well. And that was a situation probably that was sparked by the fact that they [the bank] never had a tradition . . . in arb trading. . . . There were losses. . . . Some manager didn't like the idea of [the bank] having these big positions that were showing this big volatility, and they decided to bail out. . . . [The] U.K. swap spread is one of those trades that you know that if you hold the [position] until its maturity you're probably going to make money. But if there are managers out there that can't stand the daily volatility . . . then that's when you're in trouble. (Kaplanis interview)

In some circumstances, such a decision by management might even be anticipated by the traders: "You know that if . . . your manager sees that you're down $10 million . . . the likelihood that he will ask you to get out of this position is very high. It's not a formal stop-loss but . . . it's there." (Kaplanis interview)

In the case of hedge funds, the issue was investor rather than manager queasiness. Most funds did not have LTCM's long capital lockup: "they knew that investors were starting to drain money if they saw more than 15 percent [loss] or whatever. . . . They knew that if they showed big losses a lot of investors would want to get out. They wouldn't wait until they lost 80 percent of their money . . . so that was the behavioral constraint that led to people unwinding positions even though they knew that those positions had value in the long run. They just had no choice." (Kaplanis interview) (The fourth quarter of 1998 saw net withdrawals from hedge funds of about $6 billion.)[17]

Furthermore, as market prices moved against hedge funds, they had to transfer collateral to their counterparties or to clearinghouses, and that might also require them to raise cash by liquidating positions.

Paradoxically, another factor may have been modern risk-management practices, particularly value-at-risk. This allows senior management to control the risks incurred by trading desks by allocating them a risk limit, while avoiding detailed supervision of their trading. When a desk reaches its value-at-risk limit, it must start to liquidate its positions. Says one trader: "a proportion of the investment bank[s] out there . . . are managed by accountants, not smart people, and the accountants have said 'Well, you've hit your risk limit. Close the position.'" (Wenman interview)

One aspect of the 1998 crisis may have been—Jorion (2002) disputes it[18]—an international change in banking supervision practices that increased the significance of value-at-risk. Banks are required to set aside capital reserves to meet the various risks they face, and in 1996 they began to be allowed to use value-at-risk models to calculate the set-aside required in respect to fluctuations in the market value of their portfolios (Basle Committee on Banking Supervision 1996).

The freedom to use value-at-risk models in calculating capital requirements was attractive to banks because it generally reduced those requirements. However, it could have the consequence that as market prices move against a bank and become more volatile, they may eventually either have to liquidate positions or to raise more capital to preserve them, a slow and often unwelcome process. Even if banks were not close to being forced to make this choice, the increased prominence of value-at-risk may have contributed to pressure to liquidate positions in the face of adverse price movements and of increased volatility (Dunbar 2000; Meriwether interview).

The self-reinforcing adverse price movements of August and September 1998 had major effects on the markets in which LTCM traded. A senior hedge-fund manager not affiliated with LTCM puts it this way: "As people were forced to sell, that drove the prices even further down. Market makers quickly became overwhelmed, where the dealers, who would [normally] be willing to buy or sell those positions were simply unwilling to do it, and they either said 'Just go away: I'm not answering my phone' or set their prices at ridiculous levels." (Shaw interview)[19]

The simple fact that the crisis occurred in August, the financial markets' main holiday month and thus typically the worst time to try to sell large positions, may have exacerbated the effects of sales on prices. The price movements were certainly huge. In a single day (August 21, 1998), LTCM lost $550 million as swap spreads in the United States and the United Kingdom widened

dramatically and the planned merger between Ciena Corporation and Tellabs, Inc., in which LTCM had a large position that would profit if the merger was completed, was canceled (Perold 1999, pp. C2–C3).

Consider, for example, the premium of Royal Dutch stock over Shell stock, which, as noted above, LTCM expected to decline. In 1997, the premium had been around 8 percent. During the early months of 1998 it started to rise for unclear reasons, and during the crisis it shot up, at times exceeding 17 percent.[20]

LTCM's losses on any single position, including Royal Dutch/Shell, were tolerable. Crucially, however, correlations between the different components of LTCM's portfolio leapt upward from their typical level of 0.1 or less to around 0.7 (Leahy interview).[21] Suddenly, nearly all the positions held by LTCM began to incur losses, even though they were protected by being hedged against the obvious sources of risk and had little or nothing in common at the level of economic fundamentals. The losses were stunning in their size and their rapidity. In a single month, August 1998, LTCM lost 44 percent of its capital.

Although LTCM's August 1998 loss was huge, and far greater than had seemed plausible on the basis of LTCM's risk model, it was not in itself fatal. LTCM still had "working capital" of around $4 billion (including a largely unused credit facility of $900 million), of which only $2.1 billion was being used for financing positions (Perold 1999, p. C3). LTCM was, it seemed, a long way from being bankrupt, and it owned a portfolio of what were now (because of the widened spreads) *very* attractive arbitrage positions: positions that could reasonably be expected to converge and produce substantial profits.

Again, consider the example of LTCM's matched short position in Royal Dutch and long position in Shell. The sharp rise in the premium of Royal Dutch over Shell stock obviously meant that LTCM's position had incurred losses. However, nothing that had happened disturbed the reasoning underpinning the trade: the premium was still expected eventually to shrink dramatically or vanish. LTCM's Royal Dutch/Shell position was thus worth considerably more at a premium of 17 percent than it had been at 8 percent. If LTCM could hold the position until the now huge premium vanished (as it eventually did in the spring of 2001), it would recoup its temporary losses and indeed profit handsomely.

At this point, however, a social process of a different kind intervened: in effect, a run on the bank. "If I had lived through the Depression," says John Meriwether, "I would have been in a better position to understand events" in September 1998 (Meriwether interview). Investment banks report their results quarterly, but LTCM and other hedge funds report theirs monthly. On September 2, Meriwether faxed LTCM's investors its estimate of the August loss.

Quite reasonably, Meriwether told LTCM's investors that the huge widening in price discrepancies that had occurred in August represented an excellent arbitrage opportunity, and his fax (reproduced in Perold 1999, pp. D1–D3) invited further investment: ". . . the opportunity set in these trades at this time is believed to be among the best that LTCM has ever seen. But, as we have seen, good convergence trades can diverge further. In August, many of them diverged at a speed and to an extent that had not been seen before. LTCM thus believes that it is prudent and opportunistic to increase the level of the Fund's capital to take full advantage of this unusually attractive environment."

Meriwether's fax, intended to be private to LTCM's investors, became public almost instantly: "Five minutes after we sent out first letter . . . to our handful of shareholders, it was on the Internet." (Merton interview) In an already febrile atmosphere, news of LTCM's losses fed concern that the fund was on the brink of bankruptcy.

Fears of LTCM's collapse had two effects. First, they had an immediate effect on the prices of assets that LTCM was known or believed to hold. It held, for example, a relatively small amount of "hurricane bonds"—securities that permit insurers to "sell on" the risks of hurricanes. (On the emergence of this fascinating market, see Froot 1999.) On September 2, the price of hurricane bonds fell 20 percent, even although there had been no increase either in the probability of hurricanes or in the likely seriousness of their consequences.[22]

Assets that LTCM was believed to hold in large quantity became impossible to sell at anything other than "fire sale" prices. Beliefs about LTCM's portfolio were sometimes incorrect or exaggerated: after the crisis, LTCM was approached with an offer to buy six times the position it actually held in Danish mortgage-backed securities (Meriwether interview). Nevertheless, presumptions about its positions were accurate enough to worsen its situation considerably, and as September went on, and LTCM had to divulge more information to its counterparties, those presumptions became more accurate.

The second effect on LTCM of fears of its collapse was even more direct. Its relationship to its counterparties (those who took the other side of its trades) typically was governed by "two-way mark-to-market": as market prices moved in favor of LTCM or its counterparty, solid collateral, such as government bonds, flowed from one to the other.

In normal times, in which market prices were reasonably unequivocal, two-way mark-to-market was an eminently sensible way of controlling risk by ensuring that the consequences of a counterparty defaulting were limited. In September 1998, however, the markets within which LTCM operated had

become illiquid. There was "terror" that LTCM was going to liquidate, says Meriwether (interview).

The loss caused to a counterparty if LTCM became bankrupt could be mitigated by it getting as much collateral as possible from LTCM before that happened, and this could be achieved by "marking against" LTCM: choosing, out of the wide spectrum of plausible prices in an illiquid market, a price unfavorable to LTCM, indeed predicated on the latter's failure (Merton interview; Meriwether interview). LTCM had the contractual right to dispute unfavorable marks. In its index-options contracts, for example, such a dispute would have been arbitrated by getting price quotations from three dealers not directly involved. These dealers, however, would also be anticipating LTCM's failure, so disputing marks would not have helped greatly.

The outflows of capital resulting from unfavorable marks were particularly damaging in LTCM's index-option positions, where they cost the fund around $1 billion, nearly half of the September losses that pushed it to the brink of bankruptcy (Rosenfeld interview). In the 1998 crisis, stock-market volatility did indeed increase. But to this increase was added the results of anticipation of LTCM's likely demise.

As the prices of the options that LTCM had sold rose (in other words, as their implied volatilities increased), LTCM had to transfer collateral into accounts held by its counterparty banks. If LTCM failed, those banks would lose the hedge LTCM had provided them with (in other words, they would be "short volatility") but they would now own the collateral in the accounts. So it was in their interest that the implied volatility of the index options LTCM had sold should be as high as possible.

One banker whose bank had bought index options from LTCM says:

"When it became apparent they [LTCM] were having difficulties, we thought that if they are going to default, we're going to be short a hell of a lot of volatility. So we'd rather be short at 40 [at an implied volatility of 40 percent per annum] than 30, right? So it was clearly in our interest to mark at as high a volatility as possible. That's why everybody pushed the volatility against them, which contributed to their demise in the end." (quoted by Dunbar 2000, p. 213)

Indeed, in some cases market participants with no direct involvement with LTCM seem to have profited from its difficulties. For example, LTCM's trading often involved short positions in Treasury bond futures on the Chicago Board of Trade. To reduce those positions it would have to buy bond futures via the bank that acted as its "prime broker," Bear Stearns.

A remarkable analysis by Cai (2003) of Board of Trade data obtained from the Commodity Futures Trading Commission via the Freedom of

Information Act shows that market makers seem (perfectly legitimately) to have anticipated such purchases, buying futures a minute or two before Bear Stearns did, alerted perhaps by the arrival in the pit of brokers for Bear Stearns or by the behavior of traders acting on the firm's behalf.[23]

LTCM kept its counterparties and the Federal Reserve informed of the continuing deterioration of its financial position. On September 20, 1998, U.S. Assistant Secretary of the Treasury Gary Gensler and officials from the Federal Reserve Bank of New York met with LTCM. By then, it was clear that without outside intervention bankruptcy was inevitable.

In the words of William J. McDonough, president of the Federal Reserve Bank of New York: "Had Long-Term Capital been suddenly put into default, its counterparties would have immediately 'closed out' their positions. . . . If many firms had rushed to close out hundreds of billions of dollars in transactions simultaneously . . . there was a likelihood that a number of credit and interest rate markets would experience extreme price moves and possibly cease to function for a period of one or more days and maybe longer." (McDonough 1998, pp. 1051–1052) If "the failure of LTCM triggered the seizing up of markets," said Alan Greenspan, it "could have potentially impaired the economies of many nations, including our own" (Greenspan 1998, p. 1046).

McDonough brokered a meeting of LTCM's largest counterparties, which concluded that a re-capitalization of LTCM would be less damaging to them than a "fire sale" of its assets. Fourteen banks contributed a total of $3.6 billion, in return becoming owners of 90 percent of the fund. LTCM's investors and partners were not "bailed out." They were left with only $400 million, a mere tenth of what their holdings had recently been worth.

The re-capitalization did not immediately end the crisis. Many in the markets feared that the consortium that now owned LTCM might still decide on an abrupt liquidation. On October 15, 1998, however, the Federal Reserve cut interest rates without waiting for its regular scheduled meeting, and the emergency cut began to restore confidence. It also gradually became clear that the consortium was intent on an orderly, not a sudden, liquidation of LTCM's portfolio, which was achieved by December 1999.

The Flight to Quality and the Superportfolio

If the "superportfolio" explanation advanced in this chapter is correct, then superimposed on the flight to quality should be distinctive price movements reflecting the unraveling of the positions held by LTCM's conscious and unconscious imitators. The composition of the superportfolio is not known with any precision, but if the imitation-based explanation is correct, LTCM's

portfolio should be a reasonable proxy, and its main components are known from Perold 1999 and from the testimony of interviewees. The hypothesized specific characteristic of September 1998—"run-on-the-bank" declines in the prices of assets believed to be held by LTCM—is identical in its predicted consequences to the "unraveling superportfolio" explanation.

Convergence and relative value arbitrage as conducted by LTCM and its imitators typically involves short-selling an asset with low default risk and/or high liquidity while holding a similar asset with higher default risk and/or lower liquidity. In many cases, therefore, price movements caused by a flight to quality and by the forced sales of components of an arbitrage superportfolio cannot be distinguished.

In cases of two types, however, the predictions of the two explanations differ. Type one is cases in which there is a range of similar spreads or implied volatilities in only some of which LTCM had positions. The superportfolio explanation would then predict greater increases in the spreads or implied volatilities in which LTCM had positions than in those in which it did not (assuming that, as was in general the case, LTCM held the less liquid instrument or was short volatility, in other words had sold the options in question). If the spreads or implied volatilities genuinely are similar, the flight-to-quality explanation would, in contrast, predict similar movements of them all.

The second type of case in which the predictions of the flight-to-quality and superportfolio explanations differ is the minority of arbitrage positions in which LTCM held the more liquid instrument and was short the less liquid one (the swap-spread example discussed in appendix G is an example of this kind of situation). In such a situation, the flight-to-quality interpretation predicts a rising spread; the superportfolio explanation predicts a more slowly rising, or possibly even a falling, spread.

Several of the major positions held by LTCM in the summer of 1998 fall into either type one or type two. Consider, for example, the two sets of positions that, together, were responsible for around two-thirds of LTCM's losses: equity index options and swap spreads (Lewis 1999). Equity index options are a "type one" case. LTCM had sold large amounts of long-dated index options on all the major stock-market indices listed in table 8.1, except the Japanese Nikkei 225.[24] The implied volatilities of all rose, but the increase in Nikkei 225 implied volatilities was much smaller than in the case of the other indices. Since there was, as far as I am aware, no clear flight-to-quality reason for increased relative confidence in the future stability of the Japanese stock market, this is evidence for the superportfolio hypothesis.

Swap spreads encompass two "type two" cases (France and Germany) and also an overall "type one" comparison. Because the market in swaps is less

Table 8.1
Average implied volatilities (annualized) of five-year options on major stock-market indices. Source: JWM Partners.

	June–July 1998	September 1998	Increase (percentage points)
S&P 500 (U.S.)	23%	30.3%	7.3
FTSE 100 (U.K.)	22.9%	32.4%	9.5
CAC (France)	25.8%	32.9%	7.1
SMI (Switzerland)	26.1%	35.5%	9.4
DAX (Germany)	26.5%	35.5%	9
NK225 (Japan)	25.6%	30.3%	4.7

Table 8.2
Average swap spreads (basis points) against selected government bonds, June–September 1998. Source: JWM Partners.

	June–July 1998	September 1998	Increase
France[a]	17	23	6
U.S.[b]	41	64	23
U.K.[c]	52	92	40
Japan[d]	34	41	7

a. 6% coupon, maturing October 2025
b. 6.625% coupon, maturing May 2007
c. 8% coupon, maturing 2021
d. 2.2% coupon, maturing December 2007

liquid than that in government bonds, and because a crisis may prompt fears of bank failures (and did so in 1998), a flight to quality should increase swap spreads. Table 8.2 contrasts the behavior of swap spreads in four countries.[25] In France, LTCM was "long" the swap spread in 1998 (that is, had a position, akin to that described in the swap spread example in appendix G, which would increase in value if the spread rose). That makes France a "type two" case, one in which the effect of the superportfolio unraveling (downward pressure on the swap spread) would be opposite in direction to the effect of a flight to quality (upward pressure).

The United States and the United Kingdom (in both of which LTCM was short the swap spread in the summer of 1998) are cases in which both the flight-

to-quality and superportfolio explanations predict a rise in the swap spread. Japan is a case that adds to the overall "type one" comparison of changes in the swap spread: in Japan, LTCM had two offsetting positions that left it neutrally placed with respect to overall widening or narrowing of the spread.

As table 8.2 shows, spreads widened markedly in the United States and the United Kingdom. (The same happened in Sweden, where arbitrageurs were also short the swap spread.) In contrast, in France and Japan, swap spreads widened only more modestly during the crisis; that was also the case in Germany, another type two case in which LTCM had a long position in the swap spread akin to that in France.[26] I know of no plausible flight-to-quality explanation of these international contrasts, while they are broadly consistent with the superportfolio explanation.

Equity volatility, U.S. swap spreads, and European differential swap spreads are three of the thirteen major positions held by LTCM in the summer of 1998 (table 8.3). A further two of its positions also fall into type one or type two, as another six do to some extent. The overall pattern in table 8.3 seems clear. In all the cases for which data are available, the relative price movements of the crisis are consistent with the "superportfolio" explanation, while in five cases they are inconsistent (and in a further four, possibly inconsistent) with the flight-to-quality explanation. A flight to quality *did* take place in August and September 1998, but these data do indeed suggest that overlaying it (and sometimes acting in contradiction to it) was an unraveling superportfolio.

A simpler piece of evidence consistent with the superportfolio hypothesis is the contrast between the market reaction to the August 1998 Russian default and to the attacks of September 11, 2001, which also sparked a flight to quality. LTCM's successor fund, JWM Partners, was active then too, but its capital base was smaller and its leverage levels lower, so its arbitrage positions were considerably smaller (Silverman and Chaffin 2000). The amount of capital devoted to convergence and relative value arbitrage by other market participants such as investment banks was also much smaller (interviewees estimate possibly only a tenth as large in total).

There was thus no significant superportfolio in 2001. With a flight to quality, but no superportfolio, there was no equivalent crisis. While LTCM had been devastated in 1998, JWM Partners' broadly similar, but much smaller, portfolio emerged unscathed from September 2001: the partnership's returns in that month were "basically flat." Nor is that outcome specific to JWM Partners: the fall of 2001 saw no big hedge-fund failures, few major losses, and no significant change in the level of the main index of overall hedge-fund performance. Investors overall added to their hedge-fund holdings, rather than withdrawing capital as in 1998.[27]

Table 8.3

LTCM's thirteen major positions in August 1998 (as listed in Perold 1999, pp. C6–C7), classified by relationship to flight-to-quality and superportfolio explanations using price data from JWM Partners. Type 1: comparison of similar spreads or implied volatilities. Type 2: LTCM long the more liquid or more creditworthy instrument. Neutral: predictions of flight-to-quality and superportfolio identical. Libor: London interbank offered rate. BOT: Buoni Ordinari del Tesoro.

	Type of case	Relation of Aug.–Sept. '98 price movements to superportfolio (s) and flight-to-quality (q) explanations
Equity volatility	Type 1	Consistent with s, inconsistent with q (see text)
U.S. swap spreads	Type 1 comparison of U.S. and U.K. with	Type 1 and type 2 aspects both consistent with
European differential swap spreads	Japan; type 2 in France and Germany	s, inconsistent with q (see text)
Commercial mortgages	Type 1	Consistent with s, inconsistent with q[a]
Deutschmark/euro swap options	Types 1 and 2	Consistent with s, inconsistent with q[b]
BOTLibor vs. Libor	Element of type 2	Consistent with s; possibly inconsistent with q[c]
Yen differential swap spread	Possible type 2	Consistent with s; possibly inconsistent with q[d]
Residential mortgages	Neutral	Data not available
Sterling differential swap spread	Possible type 1	Data not available
Merger arbitrage	Possible type 1	Consistent with s; possibly inconsistent with q[e]
Corporate capital structure	Unclear	Data not available
European equity pairs	Partial type 1	Consistent with s; possibly inconsistent with q[f]
Japanese bank preference shares	Possible type 2	Data not available

a. AAA commercial mortgage-backed bonds* widened vs. Libor by 23 basis points; AA (greater default risk) corporate bonds widened 3 basis points; AAA (similar default risk) Federal National Mortgage Association debentures (e.g. 5.75% coupon maturing February 15, 2008) narrowed versus Libor swaps by 3 basis points. (Here and in other notes, * indicates an asset in which LTCM had a long position.)
b. Deutschmark/euro swap option* implied volatility fell (should rise in flight to quality); dollar swap option volatility unchanged.
c. Italian government bonds generally seen as somewhat riskier than lira Libor swaps, so BOTLibor (the yield at auction of BOTs) should rise relative to lira Libor in crisis, but fell.
d. LTCM long yen swap spread at 6-year maturity vs. short swap spread at 9-year maturity. In flight to quality, some expectation that shorter-maturity swap spreads will widen more; in fact, 9-year spread widened more.
e. Largest-ever drop in "Merger Fund" (risk arbitrage fund) price; interviewees suggest drop 3 times level accountable for by merger breaks. However, perceived risk of latter does rise during market falls.
f. Royal Dutch premium over Shell* rose. Relationship to flight to quality explanation affected by extent to which premium reflected greater Royal Dutch liquidity, which is unclear.

A Global Microstructure

One way of expressing the forms currently taken by the inextricable interweaving of the "economic" and the "social" is Knorr Cetina and Bruegger's notion of "global microstructure." The financial markets are now global in their reach, but interaction within them still takes the form of "patterns of relatedness and coordination that are . . . microsocial in character and that assemble and link global domains" (Knorr Cetina and Bruegger 2002a, p. 907).

In a sense, it was globalization that undid LTCM. "Maybe the error of Long-Term was . . . that of not realizing that the world is becoming more and more global over time," says Myron Scholes (interview). Of course, no one was more aware than LTCM's principals of globalization *as a general process* (they had surfed globalization's wave, so to speak), but they were caught unawares by the consequences of the global microstructure created by imitative arbitrage.

What happened in August and September 1998 was not simply that international markets fell in concert (that would have had little effect on LTCM), but that very particular phenomena, which at the level of economic "fundamentals" had seemed quite unrelated, suddenly started to move in close to lock-step: swap spreads, the precise shape of yield curves, the behavior of equity pairs such as Royal Dutch/Shell, and so on.

The "nature of the world had changed," says John Meriwether, "and we hadn't recognized it" (Meriwether interview). LTCM's wide diversification, both internationally and across asset classes, which he had thought kept aggregate risk at acceptably modest levels, failed to do so, because of the effects of a global microstructure rooted in one of the most basic of social processes: imitation.

An Engine, Not a Camera

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