TABLE 14-3

Description of Scenarios (Number of Tests Reported by 64 Institutions Surveyed)

Category	Historical	Prospective
Interest rates (173)	1994: Bond market crash (18)	U.S. economic crash (21)
	1997: Asian currency crisis (22)	Global economic crash (11)
	1998: LTCM, Russia crises (26)	Inflation pickup (8)
	2001: World Trade Center (30)	
Equities (86)	1994: Black Monday (83)	Geopolitical unrest (5)
	1997: Asian currency crisis (22)	Terrorist attack (5)
	2000: IT bubble bursting (6)	
	2001: World Trade Center (30)	
Currencies (56)	1992: EMS crisis (8)	Pegged-currencies breakdown (7)
	1997: Asian currency crisis (22)	
	1998: LTCM, Russia crises (26)	
Commodities (22)		Oil-price jump (11)
		Unrest in Middle East (5)
Credit (104)	1997: Asian currency crisis (22)	Emerging market crash (10)
	1998: LTCM, Russia crises (26)	Euro area economic crash (7)
	2001: World Trade Center (30)	Global economic crash (6)
Property (19)		Various episodes

Source: Basel Committee (2005b) survey of financial institutions.

TABLE 14-4

October 1987 Market Crash: Change in Market Variables

	Equities				Fixed Income			Currencies	
Date	U.S., S&P	Japan, Nikkei	U.K., FTSE	Germany, DAX	Fed Funds	3-Month T-Bill	30-year T-Bond	Yen/ $	DM/ $
Oct 19	−20.4%	−2.4%	−9.1%	−9.4%	−0.14 bp	−0.52 bp	0.01 bp	−0.2%	1.3%
Oct 20	5.3%	−14.9%	−11.4%	−1.4%	−0.77 bp	−0.62 bp	−0.76 bp	1.5%	1.7%

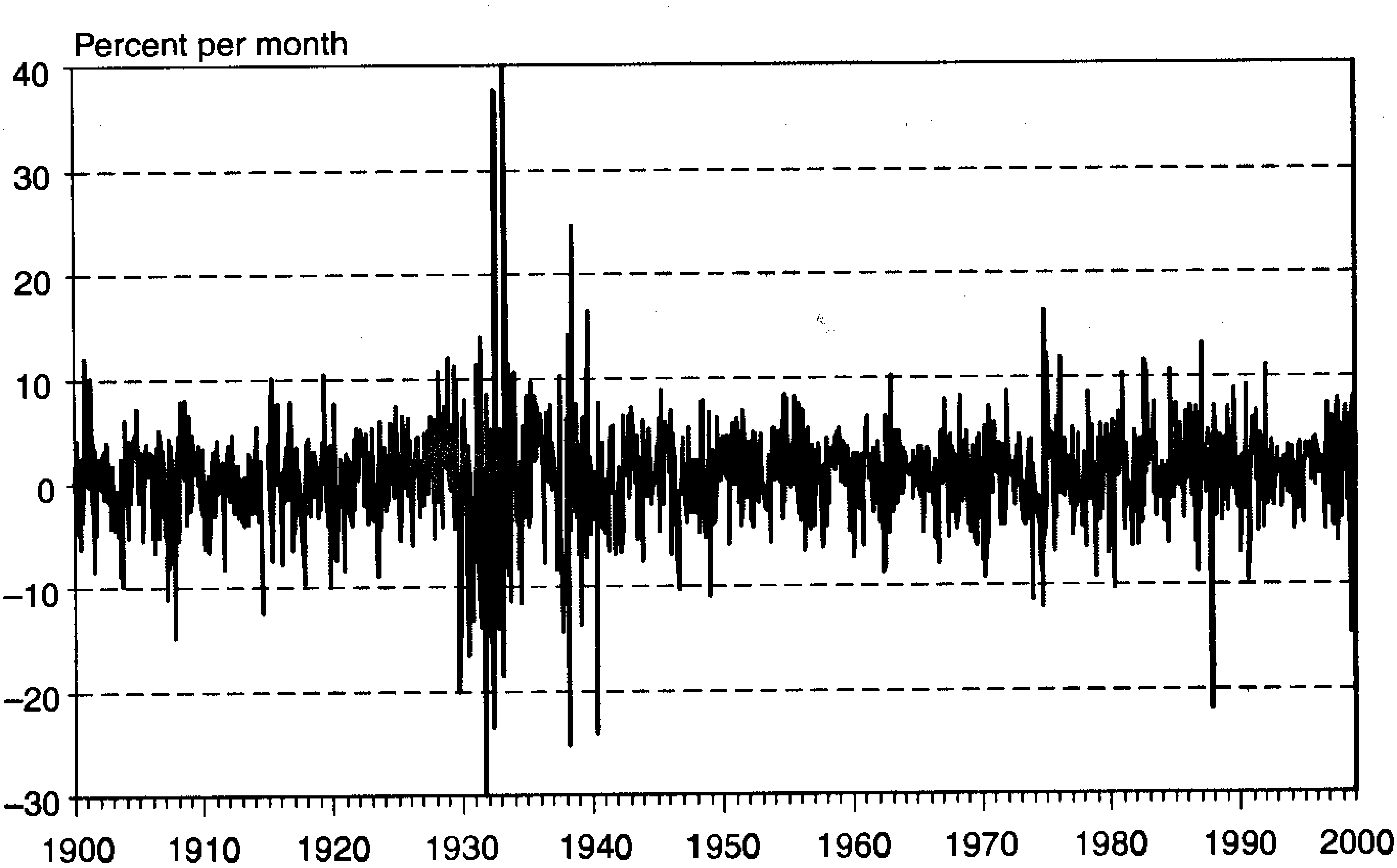
As an example, Table 14-4 details the vector of movements in risk factors for the stock market crash of October 1987. On Monday, October 19, the S&P Index lost more than 20 percent of its value. The sheer size of this movement had dramatic effects on other prices. The next day, the Nikkei fell by 15 percent. In order to forestall the failure of financial institutions, the Federal Reserve injected liquidity into the financial system, pushing short-term interest rates down by 91 basis points in 2 days. This chaos, however, apparently had little effect on currency markets. Overall, there was little diversification benefit across global stocks. As is often the case, however, long positions in bonds helped to cushion the equity losses.

Historical scenarios are quite useful to measure joint movements in financial variables. Their drawback, from the risk manager's perspective, is the limited number of extreme events. Whenever possible, very long histories should be considered. These give a long-term perspective that may be absent from recent data.

The October 1987 crash, for instance, is viewed widely as an extremely unusual event. Perhaps so if one looks only at recent data. On the other hand, a different perspective is offered by Figure 14-3, which reports monthly returns on U.S. stocks since the beginning of the century. The figure shows that if one goes back sufficiently in time, there have been many other instances of losses exceeding 20 percent over a month and that the recent past has not been unusually volatile.

FIGURE 14-3

Monthly U.S. stock returns, 1900–2000.



Likewise, events such as sovereign defaults are extremely rare. Recently, however, Russia defaulted on its domestic debt and Ecuador on its external debt. One would need to go back to the 1930s to encounter sovereign defaults on external debt. Defaults should be expected to occur, however. Otherwise, there would be no rationale for the wide yield spread observed on some sovereign debt.

As should be clear by now, the generation of relevant scenarios is a time-consuming process that requires quantitative skills as well as a good economic understanding of the factors driving financial shocks.

14.5 STRESS-TESTING MODELS AND PARAMETERS

Going back to the schematics of scenario analysis in Figure 14-2, the risk manager should critically examine all the steps in the generation of risk measures. A stress-testing process should consider not only movements in market variables but also the other components of the risk-management system, that is, the securities valuation models and the risk engine.

A distinction usually is made between *sensitivity analysis*, which examines the effect of changing the functional form of the model, and stress-testing *model parameters*, which are inputs into the model.

Let us consider sensitivity analysis first. Derivative securities can be priced using a variety of models. Interest-rate derivatives, for instance, can be valued using one- or multiple-factor models, with parameters typically estimated from historical data. Mortgage-backed securities (MBS) must in addition model prepayments. All these assumptions introduce insidious risks. Current model prices may fit the current market data but may not provide a good approximation under large movements in key variables. The Askin story (see Box 1-2) provides an example of an MBS portfolio that was thought to be hedged but led to large losses under severe interest-rate shocks. Pricing models may fail in changing environments.

Likewise, simplifications in the risk measurement system also may create hidden risks. For example, bond mapping replaces a continuous yield curve by a finite number of risk factors. If there is insufficient *granularity*, or detail, in the choice of the risk factors, the portfolio could be exposed to losses that are not measured by the risk management system.

Turning to *model parameters*, pricing and risk management systems rely on particular input data, such as a set of volatilities and correlations. Correlations, however, may deviate sharply from historical averages in times of stress. A key issue is whether a traditional variance-covariance-based VAR system provides adequate measures of risk when historical correlation patterns break down.

To some extent, this question can be answered directly by scenario analysis based on historical data. It is also informative, however, to check how sensitive a VAR number is to changes in the risk measures. As will be seen in the example of LTCM, this is especially important if the same period is used to measure risk and optimize the portfolio.

As an example, consider a covariance matrix measured with recent data that shows a high correlation between two series. The risk manager, however, cannot believe that this high correlation will remain in the future and could alter the covariance matrix toward values that are considered reasonable.[3] The stress test then compares the new VAR measure with the original one.

In all these cases, there is no simple rule to follow for stress testing. Rather, the risk manager must be aware of limitations, assumptions, and measurement errors in the system. Stress testing can be described as the art of checking whether the risk forecasts are robust to changes in the structure of the system.

14.6 POLICY RESPONSES

The main function of stress tests is to communicate and understand the risks that the institution is exposed to. The next question is what to do if the size of the stress loss appears unacceptably large. This is the crux of the issue with stress testing. Too often stress-testing results are ignored because they create large losses that are dismissed as irrelevant.

Indeed, institutions do not need to withstand every single state of the world. Central banks, in particular, are supposed to provide protection against systemic banking crises. Likewise, there is little point in trying to protect against a widespread nuclear war.

Relevant scenarios, however, require careful planning. One response is for the institution to set aside enough *economic capital* to absorb the worst losses revealed by stress tests. In many cases, however, this amount

[3] This is no easy matter because changing some entries manually could produce an inconsistent matrix, which is not positive semidefinite (see Chapter 8). A positive-semidefinite matrix ensures that for any value of the vector w, the product $w'\Sigma w$ will never be negative. Rebonato and Jäckel (1999) describe methods to ensure that this will be the case.

BOX 14-2

STRESS TESTING'S BENEFITS

A risk manager at a U.S. investment bank recalls that in December 1997 stress tests showed that the firm could be put in jeopardy should Russia default on its debt. The firm reduced its exposure to Russia in part through the purchase of credit derivatives.

The bank was able to ride the turmoil but still suffered losses owing to the fact that some counterparties defaulted on the credit protection. This illustrates that stress testing generally is useful but still is a subjective exercise that cannot possibly cover all contingencies.

may be much too large, which will make it uneconomical. A number of other actions can be considered, though. The institution could

- Purchase protection or insurance for the events in question (although this may transform market risk into counterparty risk)
- Modify the portfolio to decrease the impact of a particular event through exposure reduction or diversification across assets
- Restructure the business or product mix for better diversification
- Develop a plan for a corrective course of action should a particular scenario start to unfold
- Prepare sources of alternative funding should the portfolio liquidity suffer

Risk limits often are based on stress-test results, in addition to the usual VAR or notional-amount limits. This plan of action should help to ensure that the institution will survive this scenario, as shown in Box 14-2.

14.7 CONCLUSIONS

While VAR focuses on the dispersion of revenues, stress testing instead examines the tails. Stress testing is an essential component of a risk management system because it can help to identify crucial vulnerabilities in an institution's position. The methodology of stress testing also applies to credit and operational risks.

In some sense, stress testing can be viewed as an extension of the historical simulation method at increasingly higher confidence levels.

Stress testing, however, is a complement to standard VAR methods because it allows users to include scenarios that did not occur over the VAR window but nonetheless are likely. It also allows risk managers to assess "blind spots" in their pricing or risk management systems. Stress testing can help to ensure the survival of an institution in times of market turmoil.

The drawback of the method is that it is highly subjective. Bad or implausible scenarios will lead to irrelevant potential losses. Even worse, plausible scenarios may not be considered. The history of some firms has shown that people can be very bad at predicting extreme situations. Generally, stress-test results are presented without an attached probability, which makes them difficult to interpret. Unlike VAR, stress testing can lead to a large amount of unfiltered information. There may be a temptation for the risk manager to produce large numbers of scenarios just to be sure that any likely scenario is covered. The problem is that this makes it harder for top management to decide what to do.

Overall, stress testing should be considered an essential complement to rather than a replacement for traditional VAR measures. Stress testing is useful to evaluate the worst-case effect of large movements in key variables. This is akin to drawing a few points in the extreme tails: useful information, but only after the rest of the distribution has been specified. Still, stress testing provides a useful reminder that VAR is no guarantee of a worst-case loss.

QUESTIONS

1. Why should VAR measures be supplemented by portfolio stress testing?
2. How is stress testing different from backtesting when evaluating risk models?
3. "Stress testing is not necessary because the same results are obtained by a VAR model with an increasing confidence level." Comment.
4. Why is unidimensional scenario analysis not sufficient for stress-testing purposes?
5. If historical scenarios automatically take into account correlations, why not rely exclusively on them?
6. What is the major difficulty in generating hypothetical stress tests across large portfolios?

7. Describe the SPAN system for setting margins on a portfolio of futures and options on the same currency.
8. A pension fund has a portfolio with \$1 billion invested in U.S. stocks and \$1 billion invested in Japanese stocks. The 99 percent 1-week VAR analysis reveals a VAR of \$112 million. The risk manager, however, is concerned about extreme moves not reflected in VAR. Compute the stress loss for the following situations:
   (a) A univariate scenario where U.S. stocks fall by 20 percent.
   (b) A univariate scenario where Japanese stocks fall by 25 percent.
   (c) A prospective scenario where U.S. stocks fall by 20 percent and Japanese stocks by 15 percent.
   (d) A prospective scenario where U.S. stocks fall by 5 percent and Japanese stocks by 25 percent. As a risk manager, which stress loss do you think would be most relevant?
9. Just to be sure, the risk manager runs a regression of the Japanese stocks on U.S. stocks and finds a slope coefficient of 0.9. Assuming that a shock of 20 percent originates from the United States, compute the predicted stress loss for the portfolio. What is the danger of this approach?
10. What is the scenario most used for stress tests of firm-wide positions, (a) The 1987 equity crash, (b) money tightening by central banks, (c) a country default, or (d) widening of credit spreads?
11. The crash of 1987 was a 20 standard deviation event. Based on the normal density function, a movement of this magnitude should never happen. In addition, it was aggravated by a failure of the stock exchange to absorb the volume of trading, which has been fixed since then. Based on this information, a portfolio manager argues that this event should not be used in stress tests. Discuss.
12. If a scenario analysis reveals unacceptably large losses, what is a possible response?

PART IV

APPLICATIONS OF RISK MANAGEMENT SYSTEMS

CHAPTER 15

Using VAR to Measure and Control Risk

At the close of each business day, tell me what the market risks are across all businesses and locations.

—Dennis Weatherstone, J.P. Morgan

So far this book has discussed the motivation, building blocks, and various approaches to value-at-risk (VAR) systems. It is now time to turn to the implementation and applications of VAR.

By now, VAR has established itself as a key building block of financial risk management systems. VAR provides a top-level view of financial risk. This is ideally suited to institutions that engage in proprietary trading but also to asset managers and other financial institutions. It is also taking hold with nonfinancial corporations such as multinationals that have significant exposure to financial risks. Indeed the VAR methodology applies not only to balance-sheet values but also to cash flows. *Cash flow at risk* (CFAR) is a straightforward extension of VAR.

At the time VAR burst onto the scene, in 1994, it was devised as a method to measure and report market risk. Financial institutions have established global risk management committees that aggregate company-wide risks into a single VAR measure that is easy to communicate to top management and shareholders. For most users, however, VAR was simply a *passive* application. They were content to use VAR to report "risk numbers" to stakeholders.

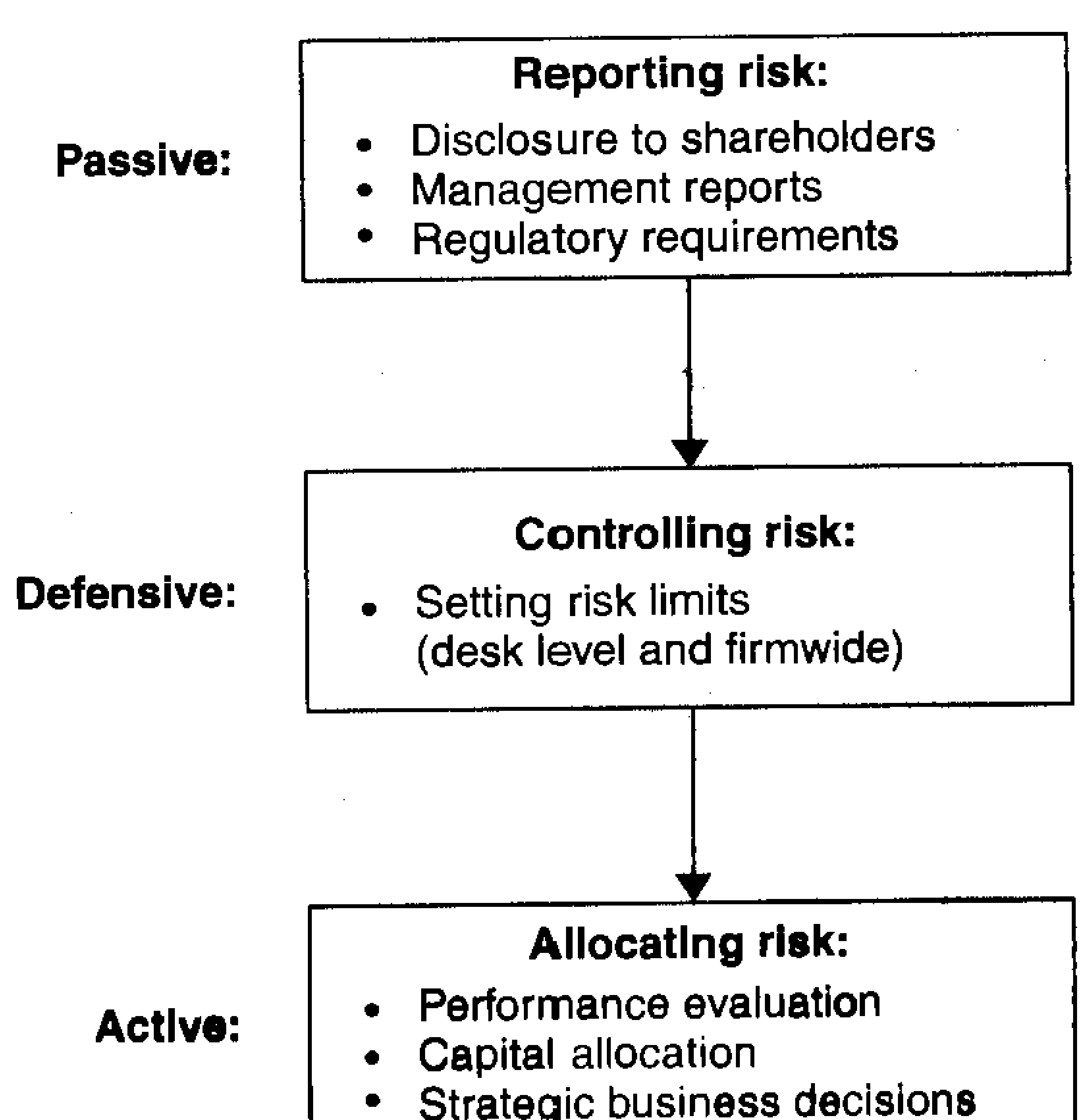
Since then, VAR has evolved into much more than a method to measure risk. Institutions have learned to apply VAR as a risk-control tool. Once a global risk management system is in place, it can be used to control risk more tightly than before. For instance, position limits for traders can be complemented by VAR limits that properly account for the leverage and risk of various instruments. At the firmwide level, VAR allows the institution to monitor its global risk exposure, taking into account diversification across business units. The firm can identify whether too many bets create unacceptable risks and, if so, reverse engineer the VAR process to identify where to cut risks. This second stage of applications represents a notable improvement over the passive reporting of risk. It is still *defensive* in nature, however.

Most recently, VAR has developed into an *active* risk management tool. With VAR tools on hand, institutions can decide how to trade off risk and return. Economic capital can be allocated as a function of business risks. Traders can be evaluated in terms of their risk-adjusted performance. Among the most advanced institutions, VAR systems are now used to identify areas of competitive advantage or sectors where they add risk-adjusted value. The evolution of VAR applications is described in Figure 15-1.

This chapter deals with the passive and defensive applications of VAR systems. Section 15.1 first reviews factors that create a need for global risk systems. It discusses situations where VAR systems are likely to be more valuable. Applications of VAR as an information-reporting tool and as a risk-control tool are analyzed in Sections 15.2 and 15.3.

FIGURE 15-1

Evolution of VAR applications.



The active risk management function, because it is so important, will be examined in Chapter 16. We also examine the application of VAR to asset managers in Chapter 17. VAR-type approaches are being extended beyond market risk to the credit risk, operational risk, and firm-wide risks, which are explained in later chapters.

15.1 WHO CAN USE VAR?

15.1.1 The Trend to Global Risk Management

VAR methods represent the culmination of a trend toward *centralized* risk management. For a number of years, financial institutions have maintained local risk management units, especially around derivatives that need to be controlled carefully because of their leverage. But only recently have institutions started to measure risk on a global basis.

This trend to global risk management is motivated by two driving factors, exposure to *new sources of risk* and the *greater volatility* of new products. With the globalization of financial markets, investors are now exposed to new sources of risk such as foreign-currency risk. Greater volatility is induced by greater risk in some underlying variables, such as exchange rates, or by the design of "exotic" products that are more sensitive to financial variables.

This trend toward centralized risk management goes back to the creation of customized over-the-counter (OTC) derivatives, such as swaps, in the 1980s. Initially, these OTC derivative transactions were immediately offset with opposing transactions, that is, swaps with similar risks. Intermediaries were essentially acting as brokers. Later, derivatives were *warehoused*, that is, kept in inventory, with dealers temporarily hedging the transaction until an offsetting transaction could be found. This led to the need for a good inventory system, as well as a good accounting system to track transactions. The next step was the transition to a *portfolio approach*. Each transaction was disaggregated into component cash flows and aggregated with other instruments in the portfolio. This is what started the process of computing VAR.

For credit-risk management, centralization is also essential. The continued expansion of derivatives markets has created new entrants with lower credit ratings and greater exposure to counterparties. A financial institution may have myriad transactions with the same counterparty, coming from various desks, such as currencies, fixed income, commodities, and so on. Even though all the desks may have a reasonable exposure when considered on an individual basis, these exposures may add up to an unacceptable risk.

Moreover, with netting agreements, the total exposure depends on the net current value of contracts covered by the agreements. All of this becomes intractable unless a global measurement system for credit risk is in place.

Large commercial and investment banks were the first to monitor on a centralized basis counterparty exposure, country, and market risks across all products and geographic locations. Asset managers and nonfinancial corporations, however, also benefit from global risk management systems.

Implementing a global risk management system, however, is no small feat. It involves integrating systems, software, and database management, which can be very expensive. In addition, it requires substantial investment in intellectual and analytical expertise. As such, it may not be appropriate for all institutions (see, for instance, Box 15-1). This is why it is useful to delineate factors that favor the development of such systems.

Diversity of Risk

Institutions exposed to a diversity of financial risks, interest rates, exchange rates, and commodity prices certainly would benefit from a global risk management system. They need a system that consistently accounts for correlations, various exposures, and volatility across risk factors. This

BOX 15-1

MERRILL'S APPROACH

Merrill's approach to global risk management differs from that of other banks. A much smaller proportion of revenues is generated by position trading. Most of its profits come from customer orders, which generally are hedged immediately.

Given Merrill's large volume of trading, VAR reports produced at the close of the previous day quickly become outdated. Perhaps this explains why Merrill's risk managers do not rely much on computer models. In their view, their best risk management tool is "distribution."

Merrill also takes the view that it has natural "business" exposure to volatility that offsets the exposure of its financial portfolio. When volatility increases, more customer orders flow in, which generates additional profits. These profits offset potential falls in the value of its inventory. The firm also keeps a positive vega (long volatility) position on its options books, just to be sure. This overall approach to the risk of the institution is an example of informal *integrated risk management.*

is especially so when the institution has a large number of independent risk-taking units whose risks need to be aggregated at the highest levels. In contrast, institutions that are exposed to one source of risk only may not require a sophisticated global risk management system. Savings and loans institutions, for instance, are exposed mainly to domestic interest-rate risk, in which case a simple duration measure may be sufficient.

Active Position Taking

Firms that take aggressive proprietary positions do require the discipline imposed by a global risk management system, especially if positions change quickly and if their leverage is high. On the other hand, firms that routinely match all trades have less of a need for such a system. One such example is foreign-exchange "brokers," who simply match buyers and sellers without ever taking positions. For them, a VAR system is not useful.

Complexity of Instruments

Firms that deal with complex instruments do require a centralized risk management system that allows consistent measures and controls of risk. Another benefit is that such a system requires a central repository for all trade processing, price quotes, and analytics. This provides some protection against operational risk, including fraud and model risk.

15.1.2 Proprietary Trading Desks

Proprietary trading desks are the prime example of institutions that satisfy all the criteria just listed. Their business has become exposed to global sources of risk. At the same time, the desks can take aggressive positions, can operate generally independently of each other, and can deal with complex products.

Consider, for instance, an investment bank where traders are awaiting U.S. unemployment numbers. Currency traders may short the dollar; they bet on unexpectedly high figures, leading to a fall in U.S. interest rates that should push the dollar down. Bond traders also may expect joblessness to rise and go long Treasury bonds. The fall in inflationary expectations may push commodity traders to short gold. Individually, these risks may be acceptable, but as whole, they sum to a sizable bet on just one number. Global risk management provides a uniform picture of the bank's risk. It fully accounts for correlations across locations and across asset classes. It allows firms to understand their risk better and therefore to control their risk better.

TABLE 15-1

J.P. Morgan's Trading Business

	Fixed Income	Currency	Commodities	Derivatives	Equities	Emerging Markets	Proprietary	Total
Number of active locations	14	12	5	11	8	7	11	14
Number of independent risk-taking units	30	21	8	16	14	11	19	120
Thousands of transactions per day	>5	>5	<1	<1	>5	<1	<1	>20
$ billions in daily trading volume	>10	>30	1	1	<1	1	8	>50

One of the earliest applications is the famous 4:15 P.M. report at J.P. Morgan. Table 15-1 shows the global trading business of the bank in 1994. Trading activities are grouped into seven business areas, each of them active in up to 14 locations. Altogether, the bank had 120 independent risk-taking units that handle over 20,000 transactions per day with a total volume exceeding $50 billion. Although decentralized trading appears very profitable, strong central risk controls are essential to understand the global risk exposure of the bank.

At the end of the day, all trading units report their estimated profit and loss for the day, their position in a standardized mapping format, and their estimated risk profile over the next 24 hours. Corporate risk management then aggregates the information with centrally administered volatilities and correlations. This leads to the global consolidated 4:15 P.M. report, which is discussed by business managers before being sent to the board's chair. Before such reports became commonplace, banks essentially were ignorant of their aggregate risk.

15.1.3 Nonfinancial Corporations

VAR is also taking hold in the corporate world, albeit more slowly than for financial institutions. Nonfinancials usually focus more on variability in cash flows than on market values of assets and liabilities. Thus the VAR methodology can be modified to measure what has been called *cash* *flow at risk* (CFAR), which is the worst loss in cash flows at some confidence level.[1]

The first step for measuring CFAR requires delineating *economic exposures*, which represent the sensitivity of cash flows to movements in the price of the financial variable. Consider first *contractual cash flows*, such as a contract to sell goods in a foreign currency, say, the euro. This contract can be "mapped" to a long position in the euro with an economic exposure equal to the notional amount. *Anticipated exposures* are similar except that they involve some uncertainty as to the actual payment. These items can be generalized to the entire cash-flow statement. As with the usual VAR methods, this is a bottom-up approach and may be called a *pro forma approach.*

Suppose, for instance, that a U.S. corporation exports to Europe and is planning to receive a series of four quarterly payments, as described in Table 15-2. The table also reports the budgeted exchange rate and the total cash flow in dollars, which is $8.51 million. The question is, what is the CFAR?

The next step consists of describing the risk distribution of key financial variables, commodity prices, exchange rates, and interest rates. This can be done via Monte Carlo simulations. The horizon usually is selected to match the business planning cycle. Note that with longer horizons, the modeling of expected returns is increasingly important, justifying the use of cointegration techniques described in Chapter 12. This is not such a problem with short-term VAR measures because volatility dominates expected returns over short horizons.

TABLE 15-2

Cash-Flow Exposure

	Period				
	1	**2**	**3**	**4**	**Total**
Cash flow (€ million)	€2	€2.1	€1.5	€2.5	€8.1
Exchange rate ($/€)	1.02	1.04	1.06	1.08	
Cash flow ($ million)	$2.04	$2.18	$1.59	$2.70	$8.51

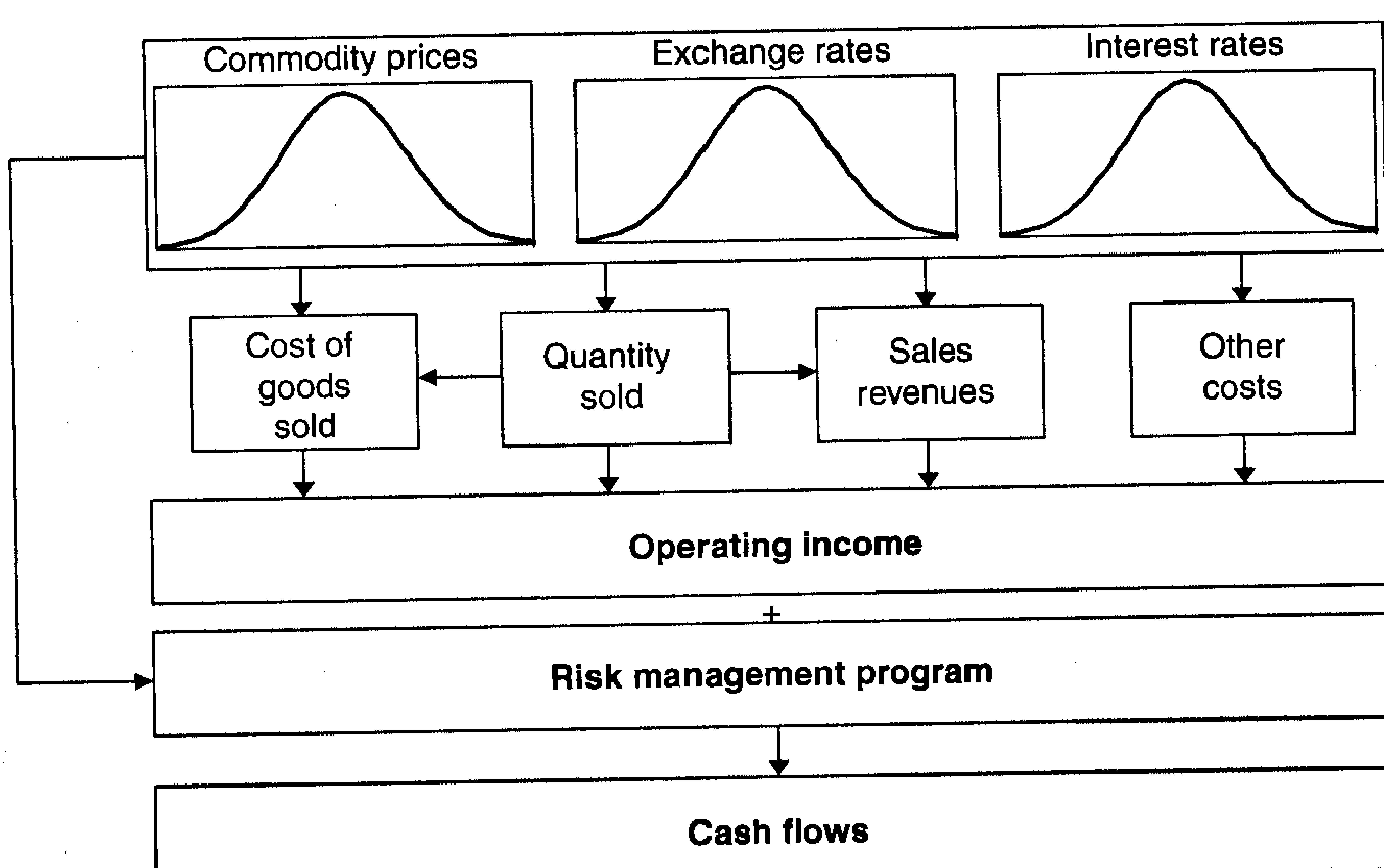
[1] See, for instance, Turner (1996).

Finally, these financial variables need to be combined with economic exposures. This is akin to attaching a simulation engine to the business cash-flow model. In the preceding example, if we assume an annual volatility of 12 percent and a trend given by the budgeted rates, simulations yield an average cash flow of $8.52 million and a 95 percent lower value of $7.40 million. Hence the worst cash-flow shortfall, or CFAR, is $1.12 million. Stein et al. (2001) analyze the distribution of historical cash flows for comparable companies, which results in a large sample of data points. They report that for an average company with $100 in assets, the CFAR for a horizon of 1 year and at the 95 percent confidence level is about $10.

This approach can be generalized to all earnings, not just specific cash flows, in which case the risk measure is *earnings at risk* (EAR). Financial variables affect *operating cash flows* through quantities sold, sales revenues, the cost of goods sold, and other costs, as shown in Figure 15-2. For instance, costs may be affected by commodity prices or, if imported, exchange rates. Sales revenues may be affected by exchange rates, if exported. Quantities and sale prices will depend on competition, however, as shown in Appendix 15.A. This *quantity uncertainty* makes it more difficult to measure CFAR than traditional VAR, where the exposures are easier to assess.

FIGURE 15-2

Measuring cash flow at risk.



Also difficult to assess are the effects of *strategic options*, also known as *operational hedges*, whereby firms can alter their marketing strategy (product or pricing) or production strategy (such as product sourcing or plant location) over the horizon in response to movements in financial variables. These options, as in the case of stop-loss or other risk-mitigating techniques, in general reduce market risk.

Once this model is constructed, risk can be measured using the VAR of the operating cash flows. A risk management program then can be set up with derivatives to lower this risk, as shown in Figure 15-2. The effectiveness of the hedging program will be measured by the reduction in VAR.

Although CFAR may not be easy to measure, there is no question that the gathering of current companywide information provides useful information. Box 15-2 illustrates the benefits of VAR in a Treasury operation.[2]

BOX 15-2

TOYOTA'S VAR

Toyota Motor Credit Corporation (TMCC) is one of the largest corporate issuers in the global bond markets. Its goal is to facilitate the sale of Toyota cars to U.S. consumers. The company raises about $7 billion a year to provide funds for car leases, which typically involve level payments over a 3-year period.

TMCC simply could lock in fixed rates to cover its assets and liabilities. The treasury manager, Jerome Lienhard, however, takes the view that raising funds at floating rates is cheaper in a positively sloped yield-curve environment.

This, however, involves taking some interest-rate risk, which is measured using VAR. TMCC runs Monte Carlo simulations of its cash inflows and outflows and discounts them to the present. These simulations allow realistic interest-rate paths as well as the inclusion of caps, or call options, that provide protection if floating rates increase.

VAR is computed using a 95 percent confidence interval over a 30-day period. This horizon gives the treasurer enough time to react if rates increase unexpectedly. Since TMCC put its VAR system in place, the portfolio VAR has been reduced from $85 million to about $30 million. This represents 1.3 percent of its capital of about $2 billion. Furthermore, TMCC estimates that hedging expenses have been reduced by $10 million, or 20 percent. Says Lienhart, "There is no question that we have gained enormous understanding of risk through the process of creating an in-house system."

[2] See also *Derivatives Strategy*, "The World According to Jerome Lienhard" (January 1999).