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JPMorgan

Introduction to RiskMetrics™

Fourth edition

- **A methodology to estimate market risk based on the Value-at-Risk approach**
- **A set of consistently calculated volatilities and correlation forecasts for use as inputs to estimate market risks**
- **A methodology and data engine for risk management systems developed by J.P. Morgan and third parties**

Market risk has become one of the most significant concerns of participants in the financial markets. Regulatory agencies, commercial and investment banks, corporates, and institutional investors are all increasingly focusing on the level of market risk incurred by their institutions. Because of the increased attention to risk, in October 1994, J.P. Morgan released **RiskMetrics™**, a market risk estimation methodology which builds on Morgan's market risk management experience, accompanied by volatility and correlation datasets covering the major financial markets.

Our motivation for promoting RiskMetrics™ is threefold:

1. We are interested in promoting greater **transparency** of market risks. Transparency is the key to risk management.
2. We want to provide a **benchmark** for market risk measurement to allow comparison of risks. Risks can only be compared when they are measured with the same yardstick.
3. We are making **sound advice** available to our clients on managing their market risks. We describe the RiskMetrics™ methodology as the basis to understanding and evaluating risk management techniques.

RiskMetrics™ is based on, but differs significantly from, the system developed by J.P. Morgan for the measurement, management, and control of market risks in its trading, arbitrage, and own account investment activities. **We remind our readers that no amount of sophisticated analytics will replace experience and professional judgment in managing risks.** RiskMetrics™ should thus be seen as nothing more than a high-quality toolbox for the professional risk manager involved in financial markets and is not a guarantee of specific results.

Why the current interest in discussing methodology and implementation of market risk monitoring?

The answer lies in the significant changes that the financial markets have undergone over the last two decades. **First**, global securities markets have expanded and both exchange-traded and over-the-counter derivatives have become a major component of the markets. In addition, new instruments such as FRA's have been introduced, made more complex, or their usage extended, e.g., commodity swaps, and there is more active balance sheet management.

These developments, along with advances in computer technology, have gone hand in hand with changes in management practices. Many firms are moving away from management based on accrual accounting and towards risk management based on marking-to-market positions. Increased liquidity, pricing availability and trading focus has led to the implementation of frequent revaluation of positions or the mark-to-market concept.

As balance sheets have become more liquid, the potential for frequent and accurate reporting of investment gains and losses has led an increasing number of firms to either manage or account for daily earnings from a mark-to-market perspective. The switch from accrual accounting to mark-to-market resulted in higher swings in reported returns, therefore increasing the need for managers to focus on the volatility of the underlying markets. The markets have not suddenly become more volatile, but the focus on risks through mark-to-market has highlighted the potential volatility of earnings.

Given the move to frequent revaluation, managers have become concerned with estimating the effect of changes in market conditions on the value of their positions.

Second, significant efforts have been put into developing methodologies and systems to measure investment performance. Indices for foreign exchange, fixed income securities, and equities have become commonplace and are used extensively to monitor returns, compare assets or asset classes, and allocate funds.

The somewhat exclusive focus on returns, however, has often led to incomplete performance analysis. Gross return measurement gives no indication of the costs in terms of

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risk or the estimated volatility of returns. It is commonly accepted that higher returns can only be obtained at the expense of higher risk or through diversification. While this trade-off is well known, the risk measurement component of its analysis has not yet received sufficient attention.

Market risk is just one form of risk to which participants are subject in the financial markets. Risk takes many forms and is often defined as the probability associated with a loss. The most common classifications of risk are based on the nature of the underlying uncertainty:

- **Credit risk** estimates potential losses due to the inability of a counterparty to meet its obligations.

- **Operational risk** results from the errors that can be made in instructing payments or settling transactions.

- **Liquidity risk** is associated with the inability of a firm to fund illiquid assets.

- **Market risk** involves the uncertainty of earnings resulting from changes in market conditions such as the asset prices, interest rates, volatility, and market liquidity. Market risk can be absolute or relative. **Absolute** market risk estimates a potential total loss expressed in currency terms, for example, Dollars at Risk. Trading managers focus on how much they can lose over a relatively short time horizon such as one day. This is called DEaR, Daily Earnings at Risk. In some cases, the investment horizon, or the time needed to unwind a position, is longer, such as a month. J.P. Morgan refers to this case as VaR, Value at Risk. **Relative** market risk measures the potential for under performance, i.e., estimated tracking error, against a benchmark. The investment management industry uses this version of market risk.

While most market participants have long focused on trying to quantify credit risks, very few institutions, even in the banking and securities sectors, have developed practical measures of aggregated market risk. Investors and trading managers are looking for common standards to measure market risks to better estimate the risk/return profile of individual assets, asset classes or entire firms. Notwithstanding the external constraints from the regulatory agencies, the management of financial firms has been looking for ways to measure the level of market risk incurred by their businesses given the potentially damaging effect of miscalculated risks on company earnings.

A common framework for measuring market risk has been lacking to date. While the financial industry has produced a wide variety of indices to measure return, it has done much less to facilitate the measurement of risk.

In response, J.P. Morgan has made the following products available:

1. **RiskMetrics™ VaR methodologies: a description of a series of market risk methodologies to map the cash flows of positions and estimate their market risk.** Value at Risk is an estimate, with a predefined confidence interval, of how much one can lose from holding a position over a set horizon. Potential horizons may be one day for typical trading activities or a month or longer for portfolio management. The methods described in our documentation use historical returns to forecast volatilities and correlations that are then used to estimate the market risk. These statistics can be applied across a set of asset classes covering products used by financial institutions, corporates, and institutional investors. RiskMetrics™ supports a series of VaR methodologies, from the "delta" valuation approach where changes in the value of a position are approximated by a linear function (VaR = value of position times price volatility of instrument) to a full simulation approach where all instruments are revalued under different scenarios. These alternatives for market risk estimation are described in the RiskMetrics™ Technical Document *(3rd edition, May 1995)*.

2. **RiskMetrics™ datasets: a comprehensive set of daily reestimated volatilities and correlations** across a large number of asset classes and instruments. The datasets are an important input to any risk management model. These datasets contain forecasts of financial asset volatilities and their correlations that can drive simulations of market risk. The methodology for estimating the volatilities (defined using a 95% confidence interval) and correlations is fully transparent and consistent across asset classes. Three datasets are currently available: one applicable for estimating risk over a 24 hour horizon, one designed for market participants with a 1-month horizon and the last developed to meet the requirements contained in the latest proposals from the Bank for International Settlements on the use of internal models to estimate market risk. The datasets are updated daily and distributed to the Internet and Compuserve.

Data structure

J.P. Morgan produces the three datasets of volatility and correlation estimates on over 400 instruments. In total, each dataset contains 450 volatilities and over 100,000 correlations.

RiskMetrics™ instruments and markets

	Foreign Exchange	Money Markets	Int. Rate Swaps	Gov't. Bonds	Equity Indices
Australia	x	x	x	x	x
Austria	x	x			x
Belgium	x	x	x	x	x
Canada	x	x	x	x	x
Denmark	x	x	x	x	x
Finland	x	x			x
France	x	x	x	x	x
Germany	x	x	x	x	x
Hong Kong	x	x	x		x
Ireland	x	x	x	x	x
Italy	x	x	x	x	x
Japan	x	x	x	x	x
Netherlands	x	x	x	x	x
New Zealand	x	x	x	x	x
Norway	x	x			x
Portugal	x	x			x
Singapore	x	x			x
Spain	x	x	x	x	x
Sweden	x	x	x	x	x
Switzerland	x	x	x		x
U.K.	x	x	x	x	x
U.S.	x	x	x	x	x
ECU	x	x	x	x	

The RiskMetrics™ datasets cover foreign exchange, money markets, interest rate swaps, bonds, and equity indices in 23 countries, along with commodities.

Complete term structure data, varying according to currency, is available for most fixed income instruments. Commodity term structure data is provided using liquid futures and spot data where available. Energy commodities include West Texas Intermediate (WTI), Heating oil, Unleaded gas, and Natural gas. Metals include Aluminum, Copper, Nickel, and Zinc. Precious metals include Gold, Silver, and Platinum.

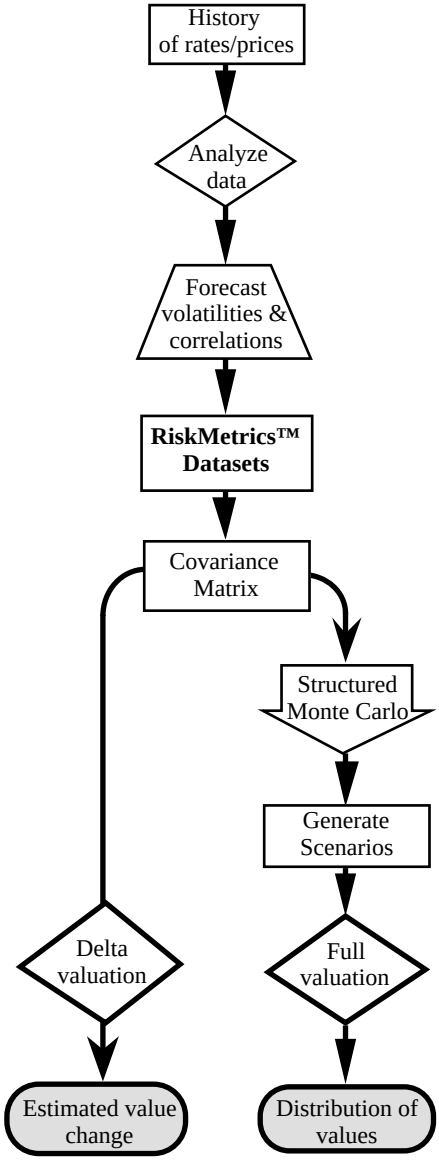
For a detailed description of the data structure, please refer to the *RiskMetrics™ Technical Document.*

Implementing market risk management

At all levels of the risk management process, be they individual position (micro), portfolio (macro) or global business lines (strategic), the risk management process should meet a number of attributes:

- **Transparency of risk** is of paramount importance because it is often the unforeseen risks which cause the biggest problems. Risks will not be properly managed if they are not identified.

Use of the RiskMetrics™ datasets for VaR estimation



- **Rigorous risk measurement techniques** are the "science" portion of the discipline. The theoretical precepts behind Value at Risk are not new. The theory is based on the standard error of a Normal distribution as is Markowitz's portfolio optimization techniques from the 1950s, which have been applied to investment management for some time. Most of the recent advances have come from understanding how to apply well-known techniques to new areas such as derivatives risk management.

- **Timely, quality information** requires a significant investment in systems architecture to pull together all risk management information together at the corporate level.

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- **Diversification of risks** is the goal of a good risk management process. In addition, hidden concentrations of exposure to a single counterparty which represent under-priced risks need to be uncovered.

- **Independent oversight** of risk taking activities is now viewed as a must by practitioners and regulators.

- **Use of disciplined judgment** is the "art" aspect of the business which relies on a sound understanding of how to use risk management tools and their limitations.

Implementing a risk management process which meets these criteria often requires significant effort on the part of market participants. With RiskMetrics™, we have attempted to commoditize some of the tools required to meet the requirements listed above.

There are two major requirements to setting up a risk management framework, such as RiskMetrics™, to estimate market risks:

- **Quality data** must serve as the basis for estimating sound statistics of future market movements, i.e., volatilities and correlations. Knowledge of the data's properties is paramount and often sheds light on the reliability and performance of market risk estimates. Within the RiskMetrics™ framework, procedures have been implemented to address a number of common data problems. One is the distinction between multiple outliers and influential observations. In other cases, data may not be available because of market closures. Furthermore, data that may include prices and rates recorded at different times, i.e., non synchronous data, may cause covariances to be underestimated. Nevertheless, variance-covariance estimates may be numerically unstable.

- **A comprehensive mapping system** must represent positions in a consistent manner. Although seemingly simple, most practitioners know that the logistical problems of collecting accurate position data within an institution may be overwhelming. The first problem is to obtain accurate position data across different business areas. The second is to agree on a methodology to map positions consistently. In the fixed income world alone, there are various ways to describe the same position and its exposure to risk. A portfolio of bonds may be described in terms of its duration. This concept often is used to estimate risk but suffers from the fact that it only measures changes in value resulting from small parallel yield curve shifts. Positions may also be described as a stream of time dated principal flows. However, that approach does not correctly estimate the

(continued on page 6)

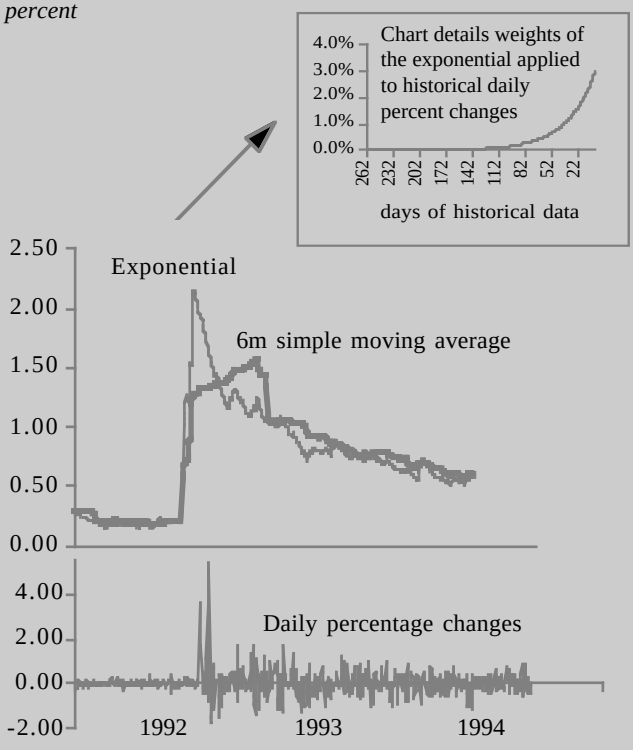
Measures of volatility and correlation

Traditional practice has been to estimate current volatility in the financial markets as the standard deviation of changes in price or yield over a set prior period, such as six months or a year. This approach explicitly allocates an identical weight to all of the observations and leads to volatility estimates that can decline abruptly once a large influential observation falls out of the measurement sample.

The RiskMetrics™ approach uses exponential moving averages of historical rate and price returns to forecast future volatility in order **to ensure responsiveness to market shocks and a subsequent gradual decline in the forecast of volatility**.

The chart below demonstrates the differences between the two approaches as they estimated volatility during the ERM crisis of September 1992 for the Lira/DM exchange rate. The exponential moving average shot up rapidly, adjusting for the devaluation of the Lira but then started to decline. **The simple 6-month moving average measure continued to rise until early 1993 and then fell by 30% in April of that year**. When compared to the actual daily changes plotted below, the exponential offers a better representation of actual volatility.

Lira/DM daily volatility



impact on risk of coupon flows when they are off current market rates. The method outlined and recommended in the *RiskMetrics™ Technical Document* is to decompose all fixed income instruments into their component cash flows and apply estimated volatilities of zero coupon rates to each individual cash flow.

The methodology outlined in the *RiskMetrics™ Technical Document* relies on a number of assumptions that must be clearly understood in order to interpret results with an objective view. Market risk measurement is as much an art as it is a science and the potential and limits of the methodology must clearly be understood.

The RiskMetrics™ methodology uses **historical return data** to forecast how the markets are likely to move in the future over a specified horizon. This is a methodological choice. There are various alternative approaches to forecasting future volatility. One is the internal forecast method where market risk professionals are asked for their estimates. The problem with this method is that it is subjective and cannot be practically implemented for a large dataset. A second method is to use implied volatilities and correlations extracted from options prices. The problem with this approach is that quality data is difficult to obtain for a wide range of rates. Good data only exist for derivatives traded on established exchanges. We, therefore, base RiskMetrics™ volatility and correlation forecasts on recently observed price and rate return histories.

The estimates of volatilities and correlations that comprise the RiskMetrics™ dataset assume that changes in prices and yields of financial instruments are **normally distributed**. Given this assumption, volatility is expressed in terms of standard deviation. The RiskMetrics™ approach has been to use 1.65 standard deviations as its measure of risk which encompasses 95% of occurrences. The assumption has two important implications:

- Occurrences outside the 95% confidence interval theoretically occur 1 day out of 20. Therefore, the estimates of volatility will underestimate risk one day a month by an unspecified amount. The simulation of worse case scenario impacts on the value of positions cannot be easily implemented using standard probability distributions.

  Stress testing scenarios must be run using various assumptions in order to provide risk managers with insights into deviations from normality and cases of event risk.

- Most return distributions have fat tails. RiskMetrics™ takes this into account by allowing volatilities to change daily and using exponential weighting.

The examples on page 7 shows how to estimate the market risk of a simple set of fixed income positions using forecast volatilities and correlations.

Practical uses of market risk information

Estimating the amount of market risk taken by an institution can serve a number of purposes:

- **Management information.** Senior management is informed of the risks run by the trading and investment operations of the institution. Ideally such information is an integral part of a comprehensive management information system which also covers areas such as credit and operational risk.

- **Setting of limits.** Position limits have traditionally been expressed in nominal terms, futures equivalents, or other denominators unrelated to the amount of risk effectively incurred. Setting limits in terms of Value at Risk has significant advantages. For example, position limits become a function of risk and positions in different markets or products can be compared through a common measure.

- **Resource allocation.** Using Value at Risk information, risk-takers can make more informed decisions about their trading strategies. From a tactical point of view, positions may be taken which maximize the return over risk potential. Strategically, profit objectives across businesses can become a function of the risk incurred. Management can use profit to risk ratios to allocate resources to specific businesses which offer more overall potential in terms of their risk/reward profile.

- **Performance evaluation.** To date, trading and position taking talent have been rewarded to a significant extent on the basis of total returns. Estimated and realized volatility of profits adds an extra dimension to performance evaluation. Ratios of P/L over risk (risk ratio) and of P/L over volatility (Sharpe Ratio) can be combined into what we would define as a trader's efficiency ratio (estimated risk/realized volatility) which measures an individual's capacity to translate estimated risk into low realized volatility of revenues.

- **Regulatory reporting.** Financial institutions such as banks and investment firms will soon have to meet capital requirements to cover the market risks that they incur as a result of their normal operations. The Basel Committee of the BIS has presented proposals to both estimate market risk and define the resulting capital requirements to be implemented in the banking sector. The European Union has approved a directive (EEC 93/6), effective January

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1996, that mandates banks and investment firms to set capital aside to cover market risks. Both of these proposals have been the object of heated debates among practitioners. In the United States, the Securities and Exchange Commission is considering imposing market risk disclosure requirements to all entities who file financial statements.

While the latest proposals from the BIS have gone a long way in addressing practitioners' concerns, a number of issues remain unresolved. The BIS proposals will allow banks to use internal models to estimate market risk, but they will also impose stringent quantitative requirements on some of the factors used in these models. First of all, the regulatory framework proposed by the BIS does not reward diversification strategies to any significant extent. Correlations can be applied within but not across asset classes to reduce risk estimates. Furthermore, the BIS has arbitrarily set certain parameters (length of historical window to measure volatility, multiplier between value at risk estimate and capital allocation, and choice of 10 day risk horizon) without any known methodological justification. As a result, the strict application of the current recommendations could lead financial institutions to overestimate market risk and subsequently be overcapitalized.

Where to get the RiskMetrics™ datasets

The RiskMetrics™ dataset is available daily by 10:30 a.m. U.S. Eastern Standard Time (based on the previous day's market close) on a number of systems which include:

- **Internet**: RiskMetrics™ publications and datasets are posted daily on a J.P. Morgan server accessible through the Internet. Users wishing to browse through the Web can use Mosaic or other equivalent browsers (URL http://www.jpmorgan.com). Files can also be accessed and downloaded via anonymous ftp.

- **CompuServe®**: Users can access the J.P. Morgan forum on the CompuServe® Information Service from around the globe, generally via a local phone call. To download RiskMetrics™ datasets and publications, type "go jpm-14" at the prompt. The RiskMetrics™ section of the J.P. Morgan forum can be accessed without a user id and password.

Subsets of the volatility and correlation data are distributed on Reuters (RKMS-Z), Telerate (17379-17385), and Bloomberg (RMMX Go).

RiskMetrics™ related products

A methodology and the underlying market data are not sufficient to enable users to implement internal market risk management systems. Therefore, J.P. Morgan has encouraged third-party consultants and software developers who are committed to developing risk management estimation and reporting tools to utilize the RiskMetrics™ methodology and data. Third parties have strongly endorsed RiskMetrics™ by incorporating it into new or existing systems. Their products are geared to providing participants in the financial markets with the tools necessary to estimate the risks resulting from exposure to market movements. For a detailed description of the various consultants and software developers who have applied RiskMetrics™ to risk management systems and other products, please refer to the *RiskMetrics™ Directory (available on-line from http://www.jpmorgan.com/MarketDataInd/RiskMetrics/Third_party_directory.html*).

Example 1: A single position Value at Risk example

Definitions

Value at Risk = the forecasted amount that may be lost given an adverse market move
= Amount of Position * Volatility of Instrument

Volatility = % of value which may be lost with a certain probability, e.g. 95%

Position

A U.S. investor is long 140 million Deutsche marks

Market/Risk Information

DEM/USD FX Volatility: 0.932%
FX Rate: 1.40 DM/USD

Value at Risk

VaR_{USD} = DEM 140 million * 0.932% / 1.40 DEM/USD = USD 932,000

Example 2: Two position Value at Risk example

Definitions

$$VaR = \sqrt{VaR_1^2 + VaR_2^2 + 2\rho_{12} VaR_1 VaR_2}$$

VaR 1 = Value at Risk for Instrument 1
VaR 2 = Value at Risk for Instrument 2
ρ_{12} = Correlation between the price movements of Instrument 1 and 2

Position

A U.S. investor is long DEM140 million 10-year German bunds
(the U.S. investor is therefore also long Deutsche marks)

Market/Risk Information

Bund volatility: 0.999%
DEM/USD FX Volatility: 0.932%
Correlation: -0.27

Interest rate risk DEM 140 million * 0.999% / 1.40 = USD999,000
FX risk DEM 140 million * 0.932% / 1.40 = USD932,000

Value at Risk

$$VaR_{USD} = \sqrt{(999,000)^2 + (932,000)^2 + 2 * (-0.27) * 999,000 * 932,000} = \text{USD 1.17 million}$$

The undiversified risk, assuming a perfect correlation between instruments, is simply the sum of the individual risks. For example with a +1.0 correlation this would be USD999,000 + USD932,000 = USD1.93 million. We look at the undiversified risk with respect to the diversified risk (our typical VaR calculation). The difference between the two is the diversification benefit to the investor due to correlation ($1.93 million - $1.17 million = $760,000).

For N positions

$$DEaR = \sqrt{\vec{V} * [C] * \vec{V}^T} \quad \text{where}$$

$$\vec{V} = \begin{bmatrix} DEaR_1 & ..... & DEaR_n \end{bmatrix} \quad \text{(DEaR vector of individual positions)}$$

$$[C] = \begin{bmatrix} 1 & .. & \rho_{n1} \\ .. & 1 & .. \\ \rho_{1n} & .. & 1 \end{bmatrix} \quad \text{(correlation matrix)}$$

$$\vec{V}^T = \begin{bmatrix} DEaR_1 \\ ..... \\ DEaR_n \end{bmatrix} \quad \text{(transposed vector of V)}$$

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RiskMetrics™ data and publications

Introduction to RiskMetrics™: An eight-page document which broadly describes the RiskMetrics™ methodology for estimating market risks.

RiskMetrics™ Technical Document: A 200-page manual describing the RiskMetrics™ methodology for estimating market risks. It specifies how financial instruments should be mapped and describes how volatilities and correlations are estimated in order to compute market risks for trading and investment horizons. The manual also describes the format of the volatility and correlation data and the sources from which daily updates can be downloaded.

RiskMetrics™ Directory: Available exclusively on the Internet, a list of consulting practices and software products that incorporate the RiskMetrics™ methodology and datasets.

RiskMetrics™ Monitor: A quarterly publication which discusses broad market risk management issues, statistical questions as well as new software products built by third-party vendors that incorporate RiskMetrics™.

RiskMetrics™ datasets: Two sets of daily estimates of future volatilities and correlations of approximately 450 rates and prices – each a total of 100,000+ data points. One set is for short-term trading risks, the other for medium-term investment risks. Datasets currently cover Foreign Exchange, Government Bond, Swap, and Equity markets in up to 22 currencies. Eleven commodities are also included. A RiskMetrics™ Regulatory dataset which incorporates the latest recommendations from the Basel Committee on the use of internal models to measure market risk is also available.

Bond Index Cash Flow Maps: A monthly insert into the Government Bond Index Monitor outlining cash flow maps of J.P. Morgan's bond indices. Available on the Internet.

Trouble accessing the Internet? If you encounter any difficulties in either accessing the J.P. Morgan home page on http://www.jpmorgan.com or downloading the RiskMetrics™ data files, you can call 1-800-JPM-INET in the United States.

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