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Corporate Risk Management

Theories and Applications

GEORGES DIONNE

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To Danielle

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Foreword

Risk management, which is omnipresent nowadays, as Georges Dionne rightly highlights, is nevertheless a relatively young field. Twenty or 30 years ago, the term would have seemed pretentious, and the natural reaction of a company director would have been to associate it with the management of insurance coverage. Not that insurance is no longer the anchor point for risk management—it still is—but the term *risk management* means a lot more than just insurance coverage. In this respect, three events have changed the content of risk management: the collapse of the Long-Term Capital Management fund in 1998, followed by that of Enron in 2001, and finally that of Lehman Brothers in 2008. These three companies were all among the best in their category, and were considered to have the most sophisticated risk management of the time. Lehman Brothers was thus rated "excellent" in risk management, a real role model. This made these failures all the more resounding. Three main lessons have been drawn from these incidents. First of all, good management of identified risks presupposes good overall governance of all the processes of the organization concerned. Next, sophistication is not enough for good risk management, because it can mask major deficiencies in terms of internal control. Finally, operational risk should not be underestimated and should be subjected to careful and reasoned assessment.

Risk management therefore goes beyond simple knowledge of the risks to which the company is exposed, their possible aggregate cost, and the techniques used to cover them. It covers governance, internal control, and compliance with regulatory requirements. In concrete terms, it covers complex processes that play out in seven logical steps:

1. First of all, a general system of good governance must be in place, which ensures the transparency of management and the rationality of the decisions made by those in charge of the organization.
2. Then the governing bodies need to set objectives for the organization concerned, in sufficient detail (what are the missions, and under what conditions they should be completed?).
3. Also, from these objectives, the governing bodies need to ascertain the organization's preferences in terms of risk or risk appetite (which risks to take or not take, minimise, etc.), bearing in mind that the objective of risk management is not to exclude risk but to control it.
4. After this, the current and emerging risks to which the organization is exposed need to be identified, and their impact on it measured in terms of frequency and severity.
5. The next step consists of deciding which measures are necessary to control these risks, by ruling them out, transferring them to other agents, or containing them within predefined limits.

6. Next, processes, thresholds, and controls must be implemented to ensure that risk control is in place throughout the organization.
7. Finally, there should be internal and external communication on risk management, depending on the legal obligations involved, market practices, and the prudential rules and standards specific to the organization and its reputation.

In this new understanding of "risk management," which emerged at the end of the twentieth century and the beginning of this one, risk management permeates the entire organization. It is thus an integral part of the company's values and culture, in which all of the company's employees, without exception, are now involved, to the point where judges may refer to it in their rulings. It is a very significant shift. This shift is not fully complete and will not be complete as long as it remains possible to hide from investors the risks to which you are exposed, and against which you are not protected. Decisions on insurance cover have become key variables with which to assess the strength of a company. They can no longer remain hidden within the departments in charge of negotiating the associated contracts. Investors, directors, and officers must be kept informed about them and must be able to assess their relevance to the company's objectives and risk appetite.

Today, good risk management forms part of a company's competitive advantages, particularly in the financial sector, and even more so in the insurance industry where you find risks on both the asset and the liability side of the balance sheet—this situation is particularly conducive to risk accumulation, which is at the root of the most extreme risks. Good risk management forms part of a company's capacity for strategic anticipation.

Georges Dionne's work fits into this renewed approach. It's important to emphasise the fact that although the consideration of risk has shaken the economy, economic analyses and works devoted to risk management and its impact on the behavior of organizations are still few and far between. Some examples are the pioneering work of the Nobel Prize–winners in Economics Lars Peter Hansen and Thomas Sargent, who raise questions in their book *Robustness* about the impact on capital management of considering risk management, and the works of Jean-Charles Rochet and Gilles Bénéplanc, who propose economic fundamentals consistent with risk management in their book *Risk Management in Turbulent Times*. It's clear that, for the purposes of optimization, risk management and capital management cannot be separated. The company seeks to maximize its current and future profitability, and therefore its growth, under the constraint of remaining solvent. And in general, the optimal situation is not one in which risk is excluded, but one where taking controlled risk enables the company to maximize its value.

Within the vast field covered by risk management, Georges Dionne's work concentrates on the motivation behind financial risk management and the measurement of its efficiency. It focuses on the management of market, credit, liquidity, and operational risk. This leads it to a detailed analysis of portfolio management and the calculation of optimal and regulatory capital. I recommend reading the entire work carefully, but I particularly appreciated the chapters devoted to analyzing the failures of LTCM and Enron, and to the subprime crisis. I also strongly recommend reading the chapters on capital and value at risk (VaR) and the most sophisticated developments in this regard within the framework of conditional value at risk (CVaR), which lies at the heart of the debate on the measurement of systemic risk. Georges Dionne talks about a textbook for students. In fact, *Corporate Risk Management: Theories*

and Applications is not just a manual, it is also a faithful companion for academics wishing to update their knowledge and for all company directors who want the most appropriate instruments to manage both the risks they have decided to take on and those that are imposed on them.

Teachers, researchers, students, and decision makers will find in Georges Dionne's work a presentation of these instruments, their economic consistency, and their intrinsic limits that is at once pedagogical and comprehensive. Anyone who is allergic to quantitative techniques need not worry about the mathematical developments contained in the text: the author has stylized and simplified them so well that they are accessible to any enthusiastic reader, while retaining the flavor of mathematic discipline. This is therefore a work to read, to engage with, and to keep at hand.

Denis Kessler
Chairman and chief executive officer of the SCOR Group
April 12, 2018

Introduction

GENERAL PRESENTATION

The study of financial risk management began after World War II. This rather young discipline aims to reduce the costs associated with risk. It covers all risk categories.

Risks cause various types of costs: physical, economic, financial, and even psychological. Some are insurable and others are not. This book concentrates on economic and financial risks that businesses and individuals face, especially those that are not anticipated, although some anticipated risks are also discussed. The costs of risk are generated not only by passive exposure to hazards, but also by risk taking in hazardous environments linked notably to the competition, technology, debt, economic conditions, climatic conditions, market imperfections, and regulations, although regulations may also mitigate the social costs of some risks.

Risk management does not imply risk aversion. It may concern risk-averse decision makers, but risk aversion is not a necessary condition for its use. It is well known that an increase in risk (mean preserving spread) decreases the welfare of risk-averse decision makers, but it also reduces the value of firms that have a concave objective function. This concavity may be obtained by a moderate risk appetite along with an exposure to nonlinear financial products, and by market imperfections such as the convexity of tax functions, or information asymmetry in financial markets.

Under the regulations governing banks and insurance companies, the risk appetite of a financial institution must be stipulated and adopted by its board of directors. This should apply as well to all businesses, for the benefit of shareholders and various stakeholders. This exercise is important because its result determines the optimal risk management actions to take. An important corollary is that firms should not cover all risks automatically; they must take only the risk management actions that maximize firms' value.

Risk is ubiquitous. Individuals, businesses, communities, and governments all face it. Risk affects welfare and includes several dimensions. In finance, it combines hazards and opportunities. It is commonly measured by modeling different possible states of nature according to their probability of occurrence and the associated consequence. This combination is linked to a probability distribution of occurrences of states of nature that have different moments. Depending on the needs and preferences of decision-making agents, these moments may yield different costs and benefits. For losses related to pure risks, mathematical expectation or mean plays a determining role. Weighting of mean and volatility prevails in the estimation of opportunities related to financial assets. Higher moments may become important when all information is not contained in the first two moments. In the study of catastrophe risks, modeling extreme losses with very low probabilities is crucial. It often involves using higher moments of the probability distribution. When statistical information is lacking, these risk measures may become inapplicable. Other approaches

of risk management must be used. Precaution is a form of risk management when agents lack information on the probabilities and consequences of the states of nature.

Information asymmetry and its consequences on risk management receive particular attention in this book. Banks cannot perfectly evaluate the risks posed by the individuals and businesses to which they make loans. This lack of information affects the risk premiums imposed by the banks, along with the forms of bank contracts and the default probabilities. Further, financial contracts affect borrowers' behavior. Choosing optimal forms of contracts is part of the risk management of financial institutions. The rating of clients' risks by banks is another form of credit risk management. In the years preceding the last financial crisis, banks put loans on the market using nonoptimal forms of securitization (without retention) in the presence of moral hazard. These choices affected their credit risk management behavior and greatly increased the probabilities of default on mortgage loans.

Information asymmetry also pertains to the governance of risk management. Do managers always choose the forms of risk management that maximize firm value? The answer may be partly linked to the different types of managerial compensation. Managers paid by stock options may not always be motivated to reduce the volatility of their firm value, compared with managers paid by shares or salary.

Information asymmetry can even justify risk management. For example, it may explain the hedging of internal financing of investment projects to avoid paying overly high interest rate premiums on external loans, arising from the difficulty that banks face when evaluating the risks associated with projects.

Information asymmetry affects risk prevention and reduces risk management when financing contracts are not written so as to give borrowers appropriate incentives. In some situations, risk becomes endogenous, which makes it more difficult to manage. Chapters 10 and 11 address this form of moral hazard.

The book is intended for graduate students in finance, financial economics, and financial engineering. It aims to provide a detailed presentation of the advanced literature on risk management. It does not use complex mathematics, but readers should have basic knowledge of statistical analysis, probability theory, applied econometrics, and finance, including portfolio management and the use of derivatives. This book does not discuss the risk management processes of risk identification, evaluation, prioritization, and control in detail, nor the execution of action plans to reduce risks under optimal scenarios. It does not address financial-product pricing or other activities related to financial engineering. Rather, it examines the motivation for risk management and the measurement of its efficiency. As the title indicates, the book is mainly dedicated to the corporate finance dimension of risk management by presenting different theoretical models that justify risk management, and by performing empirical verification of different theoretical propositions. It also proposes statistical modeling to identify the importance of different risks and of their variations according to economic cycles. Default, liquidity, and operational risks during the financial crisis that began in 2007 are analyzed in detail.

Obviously, this book cannot cover all financial risks. It focuses on market, credit, liquidity, and operational risk. It does not cover insurable risks. More specifically, it addresses portfolio market risk management and portfolio credit risk management, the use of derivatives and structured financial products, the calculation of optimal regulatory capital, prevention, conditional value at risk, regulation, and governance of risk management. It presents extreme examples that have cast doubt on

the efficiency of risk management, like the financial crisis of 2007–2009, the Enron bankruptcy in 2001, and the failure of the fund Long-Term Capital Management (LTCM) in 1998.

CONTENTS OF THE BOOK

The book contains 21 chapters. The first chapter reviews the history of risk management and of derivatives and structured financial products. A definition of risk management for nonfinancial firms is proposed. It highlights the maximization of firm value by integrating internal activities of self-protection and self-insurance with external activities like the use of market insurance, derivatives, and structured financial products.

A large part of the book contains a detailed investigation of the motivations for risk management of nonfinancial firms. By taking into account managers' risk attitude and behavior, risk management generally aims to reduce the costs associated with various risks such as those of financial distress, premiums to different partners, taxes, and investment financing. Risk management also covers dividend payments, liquidity requirements, mergers and acquisitions and firm governance. These determinants are analyzed from a theoretical standpoint (Chapters 2 and 3), and their effects are estimated using empirical studies (Chapter 4).

The concepts of value at risk (VaR) and conditional value at risk (CVaR) are explored in Chapters 5 and 8. We also present the calculation of the VaR of a financial portfolio containing equity and derivatives (Chapter 7), and the optimal choices of a portfolio under the constraint of VaR (Chapter 6). Value at risk (VaR) and conditional value at risk (CVaR) are estimated and tested using exercises. The use of VaR is also documented in Chapter 9, dedicated to the regulation of banks' market risk under the Basel Accord. We examine whether financial institutions' should use internal models rather than the standard models proposed by the Basel regulation, depending on the diversification opportunities.

Chapters 10 and 11 analyze the effects of different forms of financial contracts on managers' risk prevention activities. Empirical applications to risks of air accidents and default by venture capital corporations are presented. Chapter 10 links air accidents to the financing contracts of airlines' investment projects, and Chapter 11 analyzes how financing of venture capital affects the default probabilities of new innovative or technological businesses that need financing. A test for the presence of residual asymmetric information in the portfolio of a venture capital firm is presented, using methodologies developed during the recent years.

Next, we analyze various risks. Chapters 12 and 13 cover credit risk. Chapter 12 proposes a theoretical and empirical model of scoring of bank borrowers' default risk, and Chapter 13 presents the CreditMetrics model of risk management of default of a bond portfolio. This type of model lets banks calculate the capital required to satisfy the regulatory requirements linked to the credit risk of their financial asset portfolio or loan portfolio. This model is distinguished by its consideration of correlations between different assets in the portfolio.

Chapters 14 and 15 present empirical analyses of operational and liquidity risk. In these chapters we propose regime models that we test on data collected during the financial crisis of 2007–2009. Data on operational risk come from American banks that hold assets of $1 billion or more. We show that consideration of Markov

regimes reduces regulatory capital. Data on liquidity risk are taken from a private bond portfolio. We use CDS premiums to measure the default risk of bonds, and we apply principal component analysis to create an illiquidity index, based on different illiquidity measures. We show that liquidity risk was a key element in bonds' credit spreads during the most recent financial crisis.

Chapter 16 proposes an analysis of the LTCM fund debacle, caused by the exaggerated use of leverage and poor risk management. The managers exposed the aggregate portfolio to credit and liquidity risks by considering only very short-term market risk. Chapter 17 describes the mismanagement of different structured products, including CDOs (collateral debt obligations), during the years leading up to the financial crisis of 2007–2009.

Chapter 18 analyzes the governance of risk management at financial institutions in relation to the Enron bankruptcy and the last financial crisis. Chapter 19 reviews recent contributions on the industrial organization of risk management and Chapter 20 covers the effect of risk management on firm value. Lastly, five detailed exercises are presented in Chapter 21. The Excel files containing the solutions to these exercises are available at: https://chairegestiondesrisques.hec.ca/en/seminars-and-publications/book-Wiley.

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GENERAL REFERENCES

Bolton, P., and Dewatripont, M., 2005. *Contract Theory*. Cambridge, MA: MIT Press.

Chiappori, A.P., and Salanié, B., 2013. "Asymmetric Information in Insurance Markets: Predictions and Tests." In G. Dionne (Ed.), *Handbook of Insurance*, 2nd ed. New York: Springer, 397–422.

Christoffersen, P.F., 2012. *Elements of Financial Risk Management*, 2nd ed. Oxford, UK: Academic Press.

Courbage, C., Rey, B., and Treich, N., 2013. "Prevention and Precaution." In G. Dionne (Ed.), *Handbook of Insurance*, 2nd ed. New York: Springer, 185–204.

Crouhy, M., Galai, D., and Mark, R., 2000. *Risk Management*. New York: McGraw-Hill.

Cruz, M.G., 2002. *Modeling, Measuring and Hedging Operational Risk*. New York: John Wiley & Sons.

Dionne, G., 2013. "The Empirical Measure of Information Problems with Emphasis on Insurance Fraud and Dynamic Data." In G. Dionne (Ed.), *Handbook of Insurance*, 2nd. ed. New York: Springer, 423–448.

Dionne, G., 2013. *Handbook of Insurance*, 2nd ed. New York: Springer.

Dionne, G., and Harrington, S.E., 2014. "Insurance and Insurance Markets." In W.K. Viscusi and M. Machina (Eds.), *Handbook of the Economics of Risk and Uncertainty*. Amsterdam: North Holland, 203–261.

Doherty, N.A., 2000. *Integrated Risk Management: Techniques and Strategies for Reducing Risk*. New York: McGraw Hill.

Dowd, K., 1998. *Beyond Value at Risk*. New York: John Wiley & Sons.

Duffie, D., and Singleton, K.J., 2003. *Credit Risk: Pricing, Measurement, and Management*. Princeton, NJ: Princeton University Press.

Eeckhoudt, L., Gollier, C., and Schlesinger, H., 2005. *Economic and Financial Decisions under Risk*. Princeton, NJ: Princeton University Press.

Gouriéroux, C., and Jasiak, J., 2001. *Financial Econometrics: Problems, Models and Methods*. Princeton, NJ: Princeton University Press.

Jorion, P., 2000. *Value at Risk: The New Benchmark for Managing Financial Risk*, 2nd ed. New York: McGraw-Hill.

Laffont, J.J., 1989. *The Economics of Uncertainty and Information*. Cambridge, MA: MIT Press, MA.

Lando, D., 2004. *Credit Risk Modeling: Theory and Applications*. Princeton, NJ: Princeton University Press.

McNeil, A.J., Frey, R., and Embrechts, P., 2015. *Quantitative Risk Management: Concepts, Techniques and Tools*. Princeton, NJ: Princeton University Press.

Ritchken, P., 1996. *Derivative Markets: Theory, Strategy, and Applications*. New York: Harper Collins College Publishers.

Salanié, B., 2005. *The Economics of Contracts*, 2nd ed. Cambridge, MA: MIT Press.

Saunders, A., and Allen, L., 2010. *Credit Risk Measurement In and Out the Financial Crisis: New Approaches to Value at Risk and Other Paradigms*, 2nd ed. Hoboken, NJ: John Wiley & Sons.

Stulz, R., 2003. *Risk Management and Derivatives*. Mason, OH: Thomson South-Western.

Tirole, J., 2006. *The Theory of Corporate Finance*. Princeton, NJ: Princeton University Press, Princeton.

CHAPTER 1

Risk Management: Definition and Historical Development

Risk management began to be studied after World War II. Several sources (Crockford, 1982; Harrington and Niehaus, 2003; Williams and Heins, 1995) date the origin of modern risk management to the 1955–1964 period. Snider (1956) observed that there were no books on risk management at the time, and no universities offered courses in the subject. The first two academic books were published by Mehr and Hedges (1963) and Williams and Hems (1964). Their content covered pure risk management, which excluded financial risk. In parallel, engineers developed technological risk management models. Operational risk partly covers technological losses; today, operational risk has to be managed by firms and is regulated for banks and insurance companies. Professionals and academics also consider the political risk of projects.

Risk management has long been associated with the use of market insurance to protect individuals and companies from various losses associated with accidents (Harrington and Niehaus, 2003). In 1982, Crockford wrote: "Operational convenience continues to dictate that pure and speculative risks should be handled by different functions within a company, even though theory may argue for them being managed as one. For practical purposes, therefore, the emphasis of risk management continues to be on pure risks" (p. 171). In this remark, speculative risks were more related to financial risks than to the current definition of speculative risks, and pure risks were related to insurable risks.

New forms of pure risk management emerged during the mid-1950s as alternatives to market insurance when different types of insurance coverage became very costly and incomplete. Several business risks were costly or impossible to insure. During the 1960s, contingent planning activities were developed, and various risk prevention/self-protection and self-insurance activities against certain losses were put into place. Protection activities and coverage for work-related illnesses and accidents also began within companies during this period.

The use of derivatives as instruments to manage insurable and uninsurable risk began in the 1970s, and developed very quickly during the 1980s.[1] It was also in the 1980s that companies began to consider financial risk management or portfolio risk management. Financial risk management became complementary to pure risk management for many companies. Financial institutions, including banks and insurance

[1]Before the 1970s, derivatives were rarely used to cover financial products. They were mainly limited to agricultural products.

companies, intensified their market risk and credit risk management activities during the 1980s. Operational risk and liquidity risk management emerged in the 1990s.

International regulation of risk also began in the 1980s. Financial institutions developed internal risk management models and capital calculation formulas to protect themselves from unanticipated risks and reduce regulatory capital. At the same time, governance of risk management became essential, integrated risk management was introduced, and the chief risk officer (CRO) position was created.

In the wake of various scandals and bankruptcies resulting from poor risk management, the Sarbanes-Oxley regulation was introduced in the United States in 2002, stipulating governance rules for companies. Stock exchanges, including the New York Stock Exchange (NYSE) in 2002, also added risk management governance rules for listed companies (Blanchard and Dionne, 2004). However, all these regulations, rules, and risk management methods did not suffice to prevent the financial crisis that began in 2007. It is not necessarily the models of risk management that were inefficient, but rather their application and enforcement. It is well known that managers in various markets regularly skirt the regulation and rules. However, it seems that deviant actions had become much more common in the years preceding the financial crisis, a trend the regulatory authorities did not anticipate, notice, or, evidently, reprimand.

In this chapter, we review the history of corporate financial and nonfinancial risk management. We present the major milestones and analyze the main stages and events that fueled its development. Finally we propose a general definition of risk management.

1.1 HISTORY OF RISK MANAGEMENT

Risk management is a relatively recent corporate function. Historical milestones are helpful to illustrate its evolution. Modern risk management started after 1955. Since the early 1970s, the concept of financial risk management has evolved considerably. Notably, risk management has become less limited to market insurance coverage, which is now considered a competing protection tool that complements several other risk management activities. After World War II, large companies with diversified portfolios of physical assets began to develop self-insurance against risks, which they covered as effectively as insurers for many small risks. Self-insurance covers the financial consequences of an adverse event or losses from an accident (Ehrlich and Becker, 1972; Dionne and Eeckhoudt, 1985). A simple self-insurance activity involves creating a fairly liquid reserve of funds to cover losses resulting from an accident or a negative market fluctuation. Ex ante risk mitigation, now frequently used to reduce financial consequences related to natural catastrophes, is a form of self-insurance.

Self-protection activities have also become very important. This type of activity affects the probabilities of losses or costs before they arise. It can also affect the conditional distribution of losses ex ante. Accident prevention is the most natural form of self-protection. Precaution is a form of self-protection applied to suspected but undefined events for which the probabilities and financial consequences are unknown. For example, a pandemic is one such event (Courbage et al., 2013). All protection and prevention activities are part of risk management.

Insurers' traditional role was seriously questioned in the United States in the 1980s, particularly during the liability insurance crisis characterized by exorbitant

premiums and partial risk coverage. In that decade, alternative forms of protection from various risks emerged, such as captives (company subsidiaries that insure various risks and reinsure the largest ones), risk retention groups (groups of companies in an industry or region that pool together to protect themselves from common risks), and finite insurance (distribution of risks over time for one unit of exposure to the risk rather than between many units of exposure).

The concept of risk management in the financial sector was revolutionized in the 1970s, when financial risk management became a priority for many companies including banks, insurers, and non-financial enterprises exposed to various price fluctuations such as risk related to interest rates, stock market returns, exchange rates, and the prices of raw materials or commodities.

This revolution was sparked by major increases in price fluctuations for the risks mentioned above. In particular, fixed currency parities disappeared, and prices of commodities became much more volatile. The risks of natural catastrophe also increased considerably. Historically, to protect themselves from these financial risks, companies used balance sheets or real activities (liquidity reserves). To increase flexibility or to reduce the cost of traditional hedging activities, derivatives were then increasingly used.

Derivatives are contracts that protect the holder of an underlying asset from certain risks. Their value depends on the value and volatility of the underlying asset, or of the value indices on which the contracts are based. The best-known derivatives are forward contracts, options, futures, and swaps. Derivatives were first viewed as forms of insurance to protect individuals and companies from major fluctuations in risks. However, speculation quickly emerged in various markets, creating other risks that are increasingly difficult to control or manage. In addition, the proliferation of derivatives made it very difficult to assess companies' global risks (specifically aggregating and identifying functional forms of distribution of prices or returns).

At the same time, the definition of risk management became more general. Risk management decisions are now financial decisions that must be evaluated based on their effect on firm or portfolio value, rather than on how well they cover certain risks. This change in the definition applies particularly to large public corporations, which, ironically, may be the companies that least need risk protection, because they are able to naturally diversify much more easily than small companies. In particular, shareholders can diversify their portfolios on financial markets at a much lower cost than that of managing the risk of companies whose shares they hold.

1.2 MILESTONES IN FINANCIAL RISK MANAGEMENT

The following tables present the important dates in the evolution of risk management (Table 1.1) and of derivatives or structured financial products (Table 1.2). The birth of modern financial theory is generally associated with the seminal work of Louis Bachelier in 1900; he was the first to use the concept of Brownian motion to analyze fluctuations in a financial asset. However, it was only in the 1930s that research on prices of financial assets began. The American Finance Association (AFA) met for the first time in 1939, in Philadelphia. Its first journal, *American Finance*, appeared in 1942. It became *The Journal of Finance* in 1946. At that time, research in finance specifically dealt with price setting, financial market efficiency, and detection of profitable strategies (including anticipation of stock prices). The year 1932 marked the

TABLE 1.1 Milestones in the history of risk management.

1730	First futures contracts on the price of rice in Japan
1864	First futures contracts on agricultural products at the Chicago Board of Trade
1900	Louis Bachelier's thesis "Théorie de la Spéculation"; Brownian motion
1932	First issue of the *Journal of Risk and Insurance*
1942	First issue of the *Journal of Finance*
1952	Publication of Markowitz's (1952) article "Portfolio Selection"
1961–1966	Treynor, Sharpe (1964), Lintner, and Mossin develop the CAPM
1963	Arrow (1963) introduces optimal insurance, moral hazard, and adverse selection
1972	Futures contracts on currencies at the Chicago Mercantile Exchange
1973	Option valuation formulas by Black and Scholes (1973) and Merton (1973)
1974	Merton's default risk model (1974)
1977	Interest rate models by Vasicek (1977) and Cox, Ingersoll, and Ross (1985)
1980–1990	Exotic options, swaptions, and stock derivatives
1979–1982	First OTC contracts in the form of swaps: currency and interest rate swaps.
1985	Creation of the Swap Dealers Association, which established the OTC exchange standards
1987	First risk management department in a bank (Merrill Lynch)
1988	Basel I
Late 1980s	Value at risk (VaR) and calculation of optimal capital
1992	Article by Heath, Jarrow, and Morton (1992) on the forward rate curve
1992	Integrated Risk Management
1992	RiskMetrics
1994–1995	First bankruptcies associated with misuse (or speculation) of derivatives: Procter & Gamble (manufacturer, rates derivatives, 1994), Orange County (management funds, derivatives on financial securities, 1994), and Barings (bank, forward contracts, 1995)
1997	CreditMetrics
1997–1998	Asian and Russian crisis and LTCM collapse
2001	Enron bankruptcy
2002	New governance rules by Sarbanes-Oxley and NYSE
2004	Basel II
2007	Beginning of the financial crisis
2009	Starting of CDS central clearing operations
2010	Basel III
2010	Dodd-Frank Act for regulating the US financial markets (including the Volcker Rule)
2011–2013	New rules for the governance of risk management
2016	Solvency II came into effect
2016	CVaR replaces VaR in Basel III regulation for market risk

Note: This table presents the main dates related to the history of risk management.

birth of the American Risk and Insurance Association. The first academic studies of insurance were published in *Journal of Insurance*, which was renamed *The Journal of Risk and Insurance* in 1964 (Weiss and Qiu, 2008). Other specialized journals followed, including *Risk Management* (formerly *The National Insurance Buyer*), published by the Risk and Insurance Management Society (RIMS), a professional association of risk managers founded in 1950, along with *The Geneva Papers of Risk and Insurance*, published by the Geneva Association since 1976.

TABLE 1.2 Main dates of the launching of derivatives and structured financial products.

1970s	Currency swaps
1972	Foreign currency futures
1973	Equity options
1979	Over-the-counter currency options
1981	Cross-currency interest rate swaps
1983	Equity index options
1983	Interest rate caps/floors
1983	Swaptions
1985	Asset-back securities (ABS)
1987	Path-dependent options (Asian, lookback, etc.)
1987	Collateralized debt obligations (CDO)
1992	CAT and futures insurance options
1993	Captions/Floortions
1994	Credit default swaps (CDS)
1994	CAT bonds
1997	Weather derivatives
2002	Collateralized fund obligations (CFO)
2017	Crypto derivatives

Note: This table presents the main appearance dates of derivative and structured financial products.

It was only in the 1950s and 1960s that researchers (Markowitz, Lintner, Treynor, Sharpe, and Mossin) undertook fundamental studies of financial decisions. This resulted in the modern theory of portfolio choice based on the Capital Asset Pricing Model (CAPM). This period was marked by revolutionary articles in finance, whose lead authors earned Nobel Prizes. Yet, it was only in the early 1970s that the main financial risk management products appeared and that the initial theoretical models of modern risk coverage were published.

Black and Scholes's model is undoubtedly the most popular of these early models. These authors were the first to propose an explicit formula for the pricing of a derivative, namely an option. This model was so revolutionary that the major finance journals refused to publish its first version. It was finally published in the *Journal of Political Economy*, in 1973. Later that year, Merton published an extension in the *Bell Journal of Economics and Management Science*. After that, risk coverage derivatives expanded quickly, spawning currency and interest rate swaps, and over-the-counter options (OTCs). Mathematical finance and the popularity of computers accelerated the growth and use of derivatives.

This period is the starting point for the intensive development of research on derivatives pricing. Although coverage of agricultural products began in Chicago in 1864 (and in Japan in 1730 for rice prices), it was only in 1972 that derivatives on financial assets surfaced in that American city (Chicago Board of Trade, CBOT). The year 1973 marked a turning point in financial history for another reason: the creation of the CBOE (Chicago Board Options Exchange), together with a clearinghouse.

The growth of the options market accelerated after the CBOE standardized contracts and developed secondary markets needed to generate sufficient liquid assets for market effectiveness (Smith, Smithson, and Wakeman, 1990). During the 1980s

and 1990s, the implementation of these hedge products sensitized market players to the risk they incur in their regular investment activities.

Concomitantly, new statistical tools were put in place in banks and rating agencies to select the clientele (e.g., credit scoring) and manage credit risk. These tools facilitated assessment of default/credit and pricing risks. The Basel Accord of 1988 imposed an international regulatory vision of credit risk.

In the late 1980s, high market volatility spurred the large US investment banks to put in place risk management departments (Field, 2003). JP Morgan developed the two best-known internal risk management models—RiskMetrics for market risk and CreditMetrics for credit risk—in 1992 and 1997. These two models highlighted the idea of measuring risks in portfolio form by considering their dependencies and using value at risk to quantify aggregate portfolio risk. The publication of the RiskMetrics model prompted broad dissemination of the value-at-risk (VaR) measure among professionals and academics alike. It was imported from insurers, which used a similar risk measure to calculate their maximum losses (MPY, or maximum probable yearly aggregate Loss; Cummins and Freifelder, 1978). VaR is the maximum value that a portfolio or company can lose during a given period of time, at a specified level of confidence. This measure also allows one to measure the optimal capital required to protect companies or portfolios from anticipated and unanticipated losses (Scaillet, 2003).

These new risk measurement tools are important instruments for calculating banks' regulatory capital under Basel regulation. They were also used to analyze the first major losses sustained in 1994 and 1995 following the misuse of derivatives (Procter & Gamble, Orange County, and Barings). Three credit risk crises followed: the Asian crisis, the Russian crisis, and the collapse of Long-Term Capital Management (LTCM). The LTCM hedge fund was overexposed to various risks. When the Asians and Russians steadily defaulted on their obligations, LTCM began to run short of liquid assets to meet its obligations; this liquidity risk quickly turned into a default risk (Jorion, 2000).

Risk management became a corporate affair in the late 1990s. The major orientation decisions in firms' management policy (and monitoring) are now made by the board of directors. Most often, the audit committee monitors these decisions, although some large financial institutions have put risk committees in place. The position of Chief Risk Officer, or CRO, became more important.

Financial hedging products were developed to cover different types of risk. The four main risks for banks are credit risk (80% of the risk of banks, including default risk), market risk (5%), operational risk (15%), and liquidity risk (not yet well quantified). Market risk represents the risk of volatile prices or asset returns, and credit risk has been associated with default risk (although recent studies estimate that the default risk corresponds to a maximum ranging from 25% to 85% of the bond credit spread; Elton et al., 2001; Dionne et al., 2010). The Basel agreement of 2004 addresses these risks. Only credit risk was covered in 1988; market risk was considered years later, in 1996. It quickly became apparent that regulatory treatment (arbitrary capital) of market risk was ill-adapted to banks' portfolio management of this risk.

Regulatory authorities consequently authorized banks to use internal models to measure market risk. In contrast, the portfolio treatment of credit risk began only in 2004 under Basel II.