# The Value of Risk Management: A Frontier Analysis*

Marcel Boyer,[†] M. Martin Boyer[‡] and René Garcia[§]

Revised March 2005

BBG.tex, March 15, 2005, 14h42

**Abstract**

To address the value of risk management, we adopt a new perpspective. We characterize the relationships between operations management and real risk management activities by postulating a transformation possibility frontier for the cash flows of the firm. We show how external changes in the market parameters defining the price of risk can affect the optimal levels of the two types of real activities within the firm. The typical separation of operations management and real risk management is a potential source of organizational inefficiency. We show that the role of financial risk management is to create flexibility to alleviate this inefficiency problem. In so doing, it does contribute indirectly to the value of the firm. An important role of the CEO is then to coordinate operations and real risk management activities as well as financial risk management activities.

JEL Classification: G22, G31, G34

Keywords: Efficiency Frontier, Risk Management, Operations Management, Price of Risk.

*We wish to thank Gordon Sick, Michel Poitevin, Bryan Campbell, Simon van Norden, participants in seminars at HEC-Montréal and CIRANO as well as in the Marseille EGRIE meeting, for their comments on earlier drafts of this paper and CIRANO for its support. Marcel Boyer gratefully acknowledges financial support from Bell Canada while René Garcia gratefully acknowledges financial support from Hydro-Québec and the Bank of Canada.

†Bell Canada Professor of industrial economics and Fellow of CIRANO and CIREQ, Université de Montréal (marcel.boyer@cirano.qc.ca)

‡CEFA Associate Professor of finance and insurance and Fellow of CIRANO, HEC-Montréal, Université de Montréal (martin.boyer@hec.ca)

§Hydro-Québec Professor of risk management and mathematical finance and Fellow of CIRANO and CIREQ, Université de Montréal (rene.garcia@umontreal.ca)

# 1 Introduction

The objective, function and value of corporate risk management remain debated issues. In 1993, the Group of 30[1] recommended that market and credit risk management should be functions independent of the day-to-day operations of the firm. Twenty years earlier, however, Mehr and Forbes (1973) argued the exact opposite. Today Holton (2004) argues that the risk management function within the firm is too close to operations, thus failing miserably the Group of 30's recommendations: Under the general supervision and responsibility of chief executive officers (CEO), chief risk officers (CRO) are now working alongside chief operating officers (COO) to maximize firm value, thus making risk management a central function of firms. Yet, in perfect financial markets, hedging risk cannot increase firm value by an irrelevance proposition discussed in Smith and Stulz (1985), which is a natural extension of the leverage irrelevance theorem of Modigliani and Miller (1958).

The modern view of risk management or hedging activities, and the standard representation of risk management as a value-adding activity, is mainly financial in nature. They can only add value if they can lower the firm's expected taxes, costs of financial distress or bankruptcy, and/or agency costs. Risk management activities allow a corporation to shift earnings from a state where taxable earnings are higher to a state where taxable earnings are lower. Thus, a firm facing a convex tax schedule could save on its expected tax bill by reducing the variability of its taxable earnings and therefore increase its value. As for the costs of financial distress or bankruptcy, risk management allows a reduction in the return that investors require so that the cost of external financing is reduced, the availability of debt is increased, and the firm may benefit even more from the tax shield associated with debt financing. As a result, the cash flows' discount rate is reduced so that the firm's value increases. Risk management can also facilitate optimal investment and add value to the firm if the cost of external financing is higher than the cost of funding projects internally. Unfortunately, the empirical evidence supporting those theories is rather weak.[2]

[1] The Group of 30 is a private not-for-profit international body composed of senior representatives of industry, governement and academia. See their 1993 study *Special Report on Global Derivatives.*

[2] Stulz (2003) provides a systematic review of the various theoretical justifications for risk management within the firm. For the convexity of the tax schedule, see Main (1983), Smith and Stulz (1985), Graham and Smith (1999), Graham and Rogers (2002) and Graham (2003), and MacKay and Moeller (2003) for the case of general cost convexity. For the lower expected cost of bankruptcy or financial distress, see Booth et al. (1984), Smith and Stulz (1985), Block and Gallagher (1986), Mayers and Smith (1990), Nance et al. (1993), Geczy et al. (1997), and Bodnar et al. (1998). For a better assessment of the performance of executives, see DeMarzo and Duffie (1995) and Breeden and Vishwanathan (1996). For improving the investment decisions, see Mayers and Smith (1987), Bessembinder (1991), and Doherty and Smith (1993). Finally, for better planning of the firm's capital needs, see

We divert from these currents by separating "real" risk management from "financial" risk management. Real risk management refers to the management of risk through the selection of a portfolio of activities related to production and capacity investment, that is real activities, and is then an integral part of all business operations decisions. Financial risk management refers to risk mitigation actions taken on or through the financial markets. As we will show, financial risk management plays a role of facilitator for value maximizing operations decisions. The management of financial risks, in its role as facilitator of cooperation and coordination in operations decisions, bring flexibility to the value generating process. It is through this flexibility that it can contribute, in an indirect but important way, to the value of the firm. This representation of risk management, in both its financial version and its real or operational version, and of traditional production and operations management allows a better-integrated vision of the respective roles of those functions within the firm. We focus on the fundamental interactions between the traditional operations management function of the firm and the real and financial risk management functions to maximize the value of the firm.

If a firm can change its operations or increase its flexibility at low cost to reduce significantly its risk without changing its expected cash flows, firm value will increase since the given expected cash flows will be discounted at a lower rate.[3] Rather than characterizing a firm by a quasi-fixed and exogenously given risk measure, we see the firm as choosing, within its feasibility set, a portfolio of activities, a generic term representing projects, strategies, policies and actions such as those related to investments, production, as well as human resources management, to obtain overall levels of expected cash flows and risk that maximize its value given the market price of risk. As such, we approach risk management, both the real risk management (RRM) and the financial risk management (FRM) functions, from the general point of view of the economics of the firm and the economics of organizations rather than from the usual financial perspective.[4] In a sense, we open the black box through which are generated the cash flows over states and time periods.

We characterize the relationship between traditional operations management activities and real risk management activities by postulating a transformation possibility frontier for the cash flows of the firm. This frontier is the envelope of all feasible vectors of cash flows over states of

Lessard (1991), and Froot et al. (1993).

[3]As noted by Stulz (2004, p.42), "A firm can become more flexible so that it has lower fixed costs in cyclical downturn. This greater flexibility translates into a lower beta."

[4]In so doing, we develop a model of the firm in the spirit of the early contributions of Fama and Miller (1972) and Cummins (1976).

nature and time periods that can be obtained from all the activities characterizing and identifying the firm as an economic entity. Hence, it accounts for the human, technological, contractual, legal and other constraints the firm is facing. The firm can modify its overall vector of cash flows and switch from one vector to another within its feasibility set by changing its portfolio of activities, implying that it stays, at a given point in time, within its frontier of possibilities. The firm can modify this frontier by changing the constraints underlying the transformation possibility set, typically through technological and organizational innovations.

Characterizing the proper relationships between financial risk management (FRM) and value asset management (VAM), the latter including both usual production and operations management (POM) and real risk management (RRM), is an important issue in organizational design, that is, in the allocation of imputability, responsibility and liability within the organization.[5] Our modelling of POM and RRM activities allows to address this issue from a new perspective. The independent roles of value asset management (VAM), including both POM and RRM, and financial risk management (FRM) are made crisper by defining explicitly their specific objectives and area of expertise.

[Insert Figure 0]

The potential sources of organizational inefficiency due to this independence in meeting their specific objectives are characterized. We discuss different, sometimes rather unorthodox, ways to solve the resulting problems if and when such inefficiencies occur. The role of the CEO in this context is twofold: first, to design a coordination strategy for POM and RRM activities within the VAM function; second, to design a coordination strategy between the VAM and FRM functions within the firm as a whole. At both levels, strict independence (operating the activities or functions in silos) and strict integration (operating the activities or functions under the same hierarchical structure) may both lead to significant inefficiencies.

Assuming the existence of a single source of risk, say the market portfolio, the traditional operations management aims to maximize the expected cash flows of the firm for a given level of market risk. Similarly, real risk management aims to minimize risk for a given level of expected cash flows. The optimal mix of POM and RRM activities maximizes the value of the firm given its efficiency frontier and the market price of risk. We show through a comparative statics analysis how external changes in the market parameters defining the price of risk can affect the

[5] A related issue is that of allocating economic capital to different divisions, products, or lines of business.

optimal levels (portfolio) of the different activities defining and characterizing the firm and its boundaries. Hence, we relate the level and type of these activities, understood as a portfolio, to exogenous market variables such as the risk premium, the market volatility and the risk-free rate. We show the role of VAM, which is to choose the optimal portfolio of activities and adjust it to changes in exogenous parameters, and FRM, which is to facilitate in a precise and explicit way the choices and adjustments that VAM must undertake. To illustrate our results, we discuss applications of our framework to different value maximizing business strategies, demand for reinsurance, and mergers and acquisitions or divestitures.

We present the model in Section 2. We perform a comparative statics analysis in Section 3. Section 4 discusses several issues associated with the actual implementation of such an approach to VAM (POM and RRM) and FRM in firms. Section 5 discusses the coordination problems between VAM activites as well as the role of financial risk management. Section 6 puts several business activities in the framework of VAM and FRM. Sections 7 extends the basic framework to an intertemporal setting. We conclude in Section 8.

# 2 The model

In this section, we describe the firm as nexus of activities, whereby the latter are characterized by an operations component and a risk component.

## 2.1 The possibility frontier and the prices of risk factors

A firm is a technology by which all cash flows $cf_{st}$ related to the activities defining the firm as an economic entity are distributed over or transformed between different states $s$ and periods $t$ $[(s,t), s \in \{1,2,\ldots,S\}, t \in \{1,2,\ldots,T\}]$ under constraints of different types, such as technological, legal, or contractual. The transformation possibility frontier of firm $j$, that is, the envelope of all feasible vectors of cash flows, given the set $\Omega_t$ of its information at time $t$, can be represented as follows:

$$G_j\left(cf_{11},\ldots,cf_{st},\ldots,cf_{ST}|\Omega_t\right)=0. \tag{1}$$

The firm modifies the vector of cash flows through changes in its portfolio of activities. The characteristics of the aggregate vector of cash flows lead to an evaluation of the firm by the financial markets. Given its "technology" represented by the function $G_j(\cdot)$, the firm chooses the mix of POM and RRM activities to reach the aggregate vector of cash flows that maximizes the value of the firm. Hence, the frontier $G_j(\cdot) = 0$ must be understood as a frontier in real terms, that is, emerging from the POM and RRM activities. We will see below how the financial risk management activities fit in this framework.

We assume that there exists $N$ factors of risk and that the firm's cash flows are valued through a multifactor model. Hence expected cash flows at different periods are discounted at a rate of return given by :

$$ER_j = R_F + \sum_{i=1}^{K} \beta_{ji} (ER_i - R_F) \tag{2}$$

where $ER_i$ is the return on risk factor or portfolio $i$.[6] We assume that the factors have been orthogonalized so that their mutual covariances are zero. We also assume for simplicity and tractability a constant expected cash flows per period $E_s(cf_{st}) = E_j \ \forall t$ and an infinite number of periods. In such a case, the value of the firm is simply:

$$V_j = \frac{E_j}{ER_j}. \tag{3}$$

Expressed in terms of cash flows, the security market line or hyperplane (2) takes the form:

$$E_j = V_j ER_j = V_j R_F + \sum_{i=1}^{K} V_j \beta_{ji} (ER_i - R_F), \tag{4}$$

where $V_j \beta_{ji}$ is the measure of risk of the firm's cash flows with respect to the $i$-th factor since

$$V_j \beta_{ji} = V_j \frac{COV(R_j, R_i)}{Var(R_i)} = \frac{COV(V_j R_j, R_i)}{Var(R_i)} = \frac{COV(cf_j, R_i)}{Var(R_i)} = \frac{COV(cf_j, R_i)}{\sigma_i^2}. \tag{5}$$

We can rewrite (4) as

$$E_j = V_j R_F + \sum_{i=1}^{N} \rho_{ji} \sigma_j \left( \frac{ER_i - R_F}{\sigma_i} \right), \tag{6}$$

where $\sigma_j$ measures the volatility of the firm's **cash flows**. The value of the firm will depend, in this context, only on $E_j$ and the scaled correlations $SCOR_{ji} = \rho_{ji}\sigma_j$ of the firm's **cash flows** with the returns on the different risk factors. We can rewrite the efficiency frontier in terms of those variables, namely $E_j$ and the $N$ values $SCOR_{ji} \equiv \rho_{ji}\sigma_j$, which are, for the sake of valuing the firm, sufficient statistics of all the activities within the firm.[7] The transformation possibility

[6] These portfolios can be constructed by regressing any given risk factor which is not a traded financial asset on the returns of a set of traded assets and use the predicted value from this regression.

[7] The firm's activities could be regrouped in different business units, or sets of activities, of the firm to give an empirically implementable content to the model.

frontier can be rewritten in terms of $E_j$ and the $SCOR_{ji}$, to obtain an analogue of the efficiency frontier $G_j(\cdot)$, as the envelope of all feasible points $(E_j, SCOR_{j1}, \ldots, SCOR_{jN})$, as follows:

$$H_j(E_j, SCOR_{j1}, \ldots, SCOR_{jN}) = 0, \tag{7}$$

which is the representation of the firm's technology we will work with.

Defining the firm's feasibility set in terms of the expected cash flows $E_j$ and the $N$ scaled correlation values $SCOR_{ji}$ has several advantages. First, it allows to measure the value of RRM and POM activities as moving the firm toward or along the frontier $H_j(\cdot) = 0$ in the $(E_j, SCOR_{j1}, \ldots, SCOR_{jN})$-space or dimensions. A change in the mix of POM and RRM activities will in general produce a change of value.[8] Second, it allows a proper aggregation of risks at the firm level by establishing a functional relationship between the risk factors and the cash flows of the many activities or business units making up the firm. Identifying the risk factors that are common to the various business units or activities and accounting for the dependencies between them is an important function in the firm, which can fall under the responsibility of a central unit or delegated to the various units. Both organizational forms may result in an inefficient real risk management and choosing the better one is an important function of CEO, CRO and COO. Third, it allows to view several activities of the firm such as value maximizing business strategies or mergers and acquisitions from a new perspective.

## 2.2 The value of the firm

The value of the firm is generated by a mix of POM activities and RRM activities whose specific roles can be defined as follows. Production and operations management is aimed at maximizing the expected cash flows of the firm for given levels of risk measured by the scaled correlations of the firm's cash flows with the returns on the different risk factors, thereby contributing to the value of the firm. Real risk management is aimed at minimizing such scaled correlations for a given level of expected cash flows, thereby contributing also the value of the firm. Hence, both groups of activities contribute to the overall objective of maximizing value. In this framework, the primary responsibility of higher level executives is to make sure that the firm's decision making processes bring it not only on its frontier but also at the optimal point on that frontier.

Let us assume for simplicity that there is a single risk factor, namely the market portfolio

[8] To draw in practice the efficient frontier for a given firm, one needs only the set of cash flows associated with the numerous activities defining the firm along with the scaled correlations of the cash flows with the risk factors.

risk. We can write[9]

$$E = VR_F + V\beta\left(ER_M - R_F\right) = VR_F + SCOR_M\left(\frac{ER_M - R_F}{\sigma_M}\right), \tag{8}$$

with $SCOR_M = \rho_M\sigma$. We can illustrate the problem of the firm in the space $(E, SCOR_M)$ as in Figure 1 where the straight lines are iso-value lines with their common slope being the market price of risk given by

$$\frac{E\left(R_M\right) - R_F}{\sigma_M}. \tag{9}$$

Each iso-value line represents the combinations of $E$ and $SCOR_M$ which at the market price of risk would have the same value. The value increases in the north west direction.

[Insert Figure 1]

The value $V$ attached to a given iso-value line can be obtained as the intercept (i.e., the zero-correlation expected cash flow level), $C_1$ or $C_2$ in Figure 2, discounted at the risk-free rate $R_F$. Hence the value of the firm $V_1$ corresponding to the iso-value line going through $A_1$ is $\frac{C_1}{R_F}$. Along the iso-value line going through $A_2$, the firm is worth $\frac{C_2}{R_F}$, which is greater than $\frac{C_1}{R_F}$ since $C_2 > C_1$.

[Insert Figure 2]

The combination of expected cash flows and cash flow scaled correlation that maximizes the firm's value is the combination at which the efficient frontier reaches the highest iso-value line. For that combination (point $A_2$ on Figure 2), the usual tangency condition holds:

> **Proposition 1:** To maximize firm value, the rate at which a firm's marginal rate of substitution between production and operations management (POM) and real risk management (RRM) activities (while remaining on its efficiency frontier) must be equal to the price of risk. In other words,
>
> $$-\frac{\partial\left(POM\right)}{\partial\left(RRM\right)} = -\left.\frac{\partial E}{\partial SCOR_M\left(cf_j, R_M\right)}\right|_{H(E,SCOR_M)=0} = \frac{E\left(R_M\right) - R_F}{\sigma_M}. \tag{10}$$

[9] We will drop the index of the firm $j$ when the context is clear and no confusion is possible.

At $A_2$ on Figure 2, the firm cannot reduce its scaled correlation without reducing the expected cash flows. At point $A_1$, however, it is possible to reduce the scaled correlation without affecting the expected cash flows because point $A_1$ is not located on the efficient frontier. The firm's POM and RRM strategies and policies are not efficient if they bring it to a situation such as point $A_1$. By better managing its real risk to reduce the scaled correlation of its cash flows and/or by better managing its operations to increase its expected cash flows, the firm is able to increase its value.

If there are two factors of risk ($N = 2$), then we have two prices of risk $\frac{E(R_1)-R_F}{\sigma_1}$ and $\frac{E(R_2)-R_F}{\sigma_2}$ and two scaled correlations of the firm's cash flows with the returns on the risk factors, $SCOR_1 = \rho_{j1}\sigma_j$ and $SCOR_2 = \rho_{j2}\sigma_j$. The firm maximizes its value at the point of tangency between the efficient (hyper)frontier and the iso-value hyperplane.

$$-\frac{\partial E}{\partial SCOR_1\left(cf_j, R_1\right)}\bigg|_{H(E,SCOR_1,SCOR_2)=0} = \frac{E\left(R_1\right)-R_F}{\sigma_1} \tag{11}$$

$$-\frac{\partial E}{\partial SCOR_2\left(cf_j, R_2\right)}\bigg|_{H(E,SCOR_1,SCOR_2)=0} = \frac{E\left(R_2\right)-R_F}{\sigma_2}. \tag{12}$$

$$\frac{\partial SCOR_2\left(cf_j, R_2\right)}{\partial SCOR_1\left(cf_j, R_1\right)}\bigg|_{H(E,SCOR_1,SCOR_2)=0} = \frac{E\left(R_1\right)-R_F}{E\left(R_2\right)-R_F}.\frac{\sigma_2}{\sigma_1} \tag{13}$$

### 2.3 The case of non-valued risks

Another important responsibility for senior executives is to make sure that there is no way to change the shape of the firm's transformation frontier that would increase its value, that is, no way to reach a higher transformation frontier. We have assumed until now that all the risk factors have a market price, so that firm value maximization is achieved at the optimal tangency point between the iso-value hyperplane and the possibility frontier. When the market does not value some risks that are nevertheless taken into consideration by the firm, the valuation problem is different.

We will illustrate this situation with two risk factors: the first is valued by the market and is represented by the market portfolio while the second is managed by the firm at some cost but is diversifiable for an outside investor so that its market value is zero. What will be the optimal level at which the firm should manage this non-valued risk? To each level of this non-valued risk corresponds a projected transformation possibility frontier in the space 'expected value'-'market-valued risk', namely $H(E, SCOR_M|SCOR_{NV}) = 0$, where $SCOR_{NV}$ is the level of non-valued risk taken by the firm. Under some reasonable assumptions about the non-valued risk (including the existence of a unique global maximum), there should be one best or maximal transformation possibility frontier in the space 'expected value'–'market-valued risk', namely $H(E, SCOR_M|SCOR^*_{NV}) = 0$. The tangency point between the highest iso-value line and this best frontier gives the maximal market value of the firm.[10]

One such risk that is not directly valued by the market is the value at risk ($VaR$). This concept has been used for risk management in financial firms and is defined as the amount of money such that there is typically a 95% or 99% probability of a portfolio losing less than that amount over a certain horizon. The idea of such a criterion is to consider that risk must be measured and managed firm-wide since a bad outcome might be offset by a good outcome. The firm will then have no deadweight costs. For non-financial firms a similar concept is defined in terms of cash flow at risk ($CaR$): $CaR$ at $p\%$ is the cash flow shortfall, defined as expected cash flow $E(C)$ minus realized cash flow $C$, such that there is a probability $p\%$ that the firm will have a larger cash flow shortfall:

$$\Pr[E(C) - C > CaR] = p\%. \tag{14}$$

How does such a measure relate to our framework? A good way to link it to our approach is to consider the single risk factor framework introduced in section 2.2. Such a risk model can be justified by assuming that cash flows are jointly normally distributed with the returns of the market portfolio. In such a context, $CaR$ at the 5% probability level will be given by 1.65 times the volatility of cash flows. Therefore, for a given correlation with the market portfolio, a $CaR$ objective will impose a constraint on how far the firm can go on its frontier: it will be the point at the intersection of the vertical raised at $\rho_{ji} \times 1.65 \times \sigma_j$, where $\sigma_j$ is the volatility of cash flows. If a firm depends solely on its cash flows to seize growth opportunities, it may want to control the risk of its cash flows and impose this additional constraint on maximizing the value of the firm. Otherwise, if it has access to financial markets to make up for a cash flow shortfall, it will be better optimizing the value of the firm.

Current practice in nonfinancial firms is to measure cash flow at risk with respect to market risks. Our framework allows to integrate risks that are not valued directly by the market but

[10] A parallel can be drawn with the production function using a non-valued or zero-cost input, such as in some cases water or air. If the production of the firm affects the quality of this input, there will an optimal amount of activity, say in terms of quantity of pollutants rejected, that will be compatible with maximizing profit. Similarly, there will an optimal amount of the non-valued risk that the firm should take in order to maximize its market value in the space 'expected value'–'market-valued risk'.

that are potentially more important to determine the optimal frontier of a firm.

## 3 Discussion of implementation issues

The approach to risk management we presented thus far supposes that everyone in the firm involved with the real risk management and the production and operations management decision process, that is, with the VAM decision process, is able to use the tools associated with the CAPM or the multifactor asset pricing model. Our theory does not prevent managers from using more sophisticated valuation techniques such as real option valuation and certainty equivalent valuation. As with the traditional view of activities as sequences of uncertain cash flows over time, the potential contributions of those approaches to project evaluation and real risk management can only be achieved if the sources of risk and the correlations are identified and properly measured. Insofar as a real options approach values the managerial flexibility embedded in a project and insofar as flexibility translates into a lower beta, the knowledge and proper use of such an approach would allow managers to better assess and manage the risk of a project and thereby to find the portfolio of activities that maximize the firm's value.

In explaining the derivation of the transformation possibility frontier between the expected value of cash flows and their risk ($SCOR$), we have assumed that there were no technical or informational issues that could prevent the Chief Executive Officer from implementing the necessary trade-offs. In reality, of course, many such issues arise. In what follows, we will sketch what we perceive as the main roadblocks to an ideal implementation of such a management tool. In particular, we will consider informational issues, dynamic issues, and issues about indivisibility and transaction costs.

A first obvious problem is the significant data collection implied by the dimension of the problem. The activities are countless in a firm and obtaining their cash flows over time is not a small task. The information collected is also likely to lack precision. Therefore, we need to recognize that the frontier will be derived under imprecise and potentially incomplete information and therefore that there will be uncertainty as to the position of the frontier. This uncertainty will directly affect the determination of the optimal mix of VAM activities, both the production and operations management activities and real risk management activities.

A parallel with mean-variance optimization in asset allocation will help us gauge the extent of the problem. It is well known in this literature that small changes in input assumptions about the returns of the assets often imply large changes in the optimized portfolio. Many portfolios may be statistically as efficient as the ones on the efficient frontier. Several statistical solutions have been proposed to account for the variability of the efficient frontier (see Michaud, 1998) and to increase the stability of the optimal portfolio (Jagannathan and Ma, 2003). Beyond these statistical solutions, one can mitigate the uncertainty associated with a detailed computation of the intertemporal cash flows by aggregating activities at the level of various organizational units. This will make the problem of gathering data generally easier given the accounting system in place and facilitate the optimization process.

Asymmetric information could also prevent a firm from attaining the activity mix that maximizes its value. Both adverse selection and moral hazard problems could impede the firm's ability to do so, not to mention the simple problem of information gathering at every level of the firm's hierarchy (see Williamson 1967, Boyer 2004). For instance if one manager has a preferred project that he does not want to dismiss, then it is quite possible that he will not choose the strategy that maximizes the firm's value. A similar situation arises if the manager chooses to invest in a preferred project that does not maximize firm value. As a result the firm will end up with a mix of activities that is suboptimal given the transformation possibility frontier that it can attain and given the price of risk in the economy.

Another important implementation difficulty lies in that, contrary to financial assets, real assets (or activities) are often indivisible. In portfolio theory, it is always implicitly assumed that since financial assets are infinitely divisible, it is always possible to be arbitrarily close to the efficient point on the frontier. When activities and assets are not infinitely divisible, for instance if some activities must be undertaken completely or not at all, attaining the theoretical value maximization portfolio of activities that maximizes firm value may not be possible.

Changing the optimal mix of activities in the firm will involve transaction costs. For example, premature termination of a project may involve penalties in terms of labor compensation or legal fees. The magnitude of the transaction costs may prevent the CEO to modify the optimal mix of activities or it may postpone a change in this optimal mix. Incorporating these transaction costs in portfolio choice is an extremely difficult issue and only partial solutions with specific cost structures, often unrealistic, are available. Transaction costs incurred in a given change of policy is just one example of sunk or irreversible costs. Moreover, changes in the mix of activities includes endogenous or manager-driven changes in the evolution of a project already under way. Future cash flows associated with a project will in general depend on managerial flexibility in modifying the course of activities over time as new information is made available.

Implementation issues are particularly critical in organizations that are characterized by a high degree of reliability and accountability. Reliability refers to the organization's capacity to follow dependable decision rules and processes in a consistent way while accountability refers to the organization's capacity to systematically manage knowledge in order to be able to take corrective actions if necessary. However, high levels of reliability and accountability must rest on reproducible and stable structures, which are themselves underpinned by standardization and routines, and therefore some level of inertia.[11] Creeping institutional inertia is a major risk for the firm as such inertia may limit its capacity to adapt to market parameter changes in a way consistent with value maximization. Boyer and Robert (2005) develop a dynamic asymmetric information principal-agent model meant to address the question of a value maximizing level of inertia in an organization. Their results suggest that the compensation of the CFO and the COO differs according to whether the information is private to the CEO or the CFO/COO. They show that it may be more valuable to let the CFO/COO be the informed parties in such a way that the 'real' authority for recommending a change in activity mix is divested.

# 4 Comparative Statics Analysis of Market Parameters

In the single risk factor representation, the market parameters of the iso-value lines are $E(R_M)$, $\sigma_M$, and $R_F$. The firm's technology, transforming scaled correlation of cash flows $SCOR \equiv SCOR(cf_j, R_M)$ into expected cash flows $E$, is represented by the efficiency frontier (7) which can be rewritten as follows with $\rho_M \equiv \rho_{jM}$ and $\sigma \equiv \sigma_j$:

$$H(E, SCOR_M) = H(E, \rho_M \sigma; Z) \tag{15}$$

where $Z$ is a vector of exogenous variables. As we will illustrate, a change in the expected return of the market portfolio rotates the iso-value lines, a change in the risk-free rate brings a rotation and a translation of the iso-value lines, and a change in the volatility of the return of the market portfolio rotates the iso-value lines.

## 4.1 Change in $E(R_M)$ or $\sigma_M$: rotation in iso-value lines

The first two parameters whose impact on the optimal VAM mix of activities we wish to study are the expected return on the market portfolio $E(R_M)$ and the volatility of those returns $\sigma_M$. They both condition the price of risk, which is the common value of the slope of the different

[11] Hannan and Freeman (1984) develop such an evolutionary model of inertia in organizations.

iso-value lines. An increase in the expected return of the market portfolio as well as a reduction of the volatility of those returns increases the slope of the iso-value lines (counterclockwise rotation).

Neither the variation in the expected return of the market portfolio nor the volatility of those returns have an impact on the firm's transformation technology so that its efficient frontier does not vary when we let $E(R_M)$ or $\sigma_M$ vary. Because the transformation technology is convex by assumption, the upper arm of the efficient frontier is concave: an increase in the expected return of the market portfolio or a reduction of the volatility of those returns increase the price of risk and shifts the efficient point, the tangency point between the efficiency frontier and the maximal iso-value line, to the left. When the expected return of the market portfolio increases or the market volatility increases, the company's best strategy is to modify its VAM activities in order to move from $A_1$ to $A_2$ in Figure 3, thus reducing $E$ and $SCOR$.

[Insert Figure 3]

**Proposition 2:** The firm reacts to an increase in the expected market return (which increases the price of risk) by modifying its real risk management activities and its production and operations management activities to reduce both its expected cash flows and the scaled correlation of its cash flows with the returns on the market portfolio.

**Proposition 3:** The firm reacts to an increase in the volatility of the returns on the market portfolio (which reduces the price of risk) by modifying its real risk management activities and its production and operations management activities to increase both its expected cash flows and the scaled correlation of its cash flows with the returns on the market portfolio.

### 4.2 Change in $R_F$: rotation and translation of the iso-value lines

An increase in the risk-free rate from $R_F$ to $R'_F$ reduces the price of risk (9) so that the iso-value lines rotate clockwise. Moreover, since the zero correlation cash flows are discounted at a higher rate than before, the intercept of a given iso-value line moves up. Hence an increase in $R_F$ both bring a clockwise rotation of the iso-value lines and a translation upwards as in Figure 4 and 5 where the iso-value line with intercept $C_1$ is changed, by the increase in the risk-free rate $R_F$, into the iso-value line with intercept $C'_1$. In both figures, the iso-value line $C'_1B$ represents all the new combinations $(E, SCOR)$ that have the same value $V$ as the combinations on the original iso-value line $C_1B$, that is, $\frac{C_1'}{R_F'} = \frac{C_1}{R_F} = V$. These two iso-value lines intersect at point $B$ where $SCOR = V\sigma_M$, that is, at the point where the firm would have a $\beta$ equal to 1.[12]

For firms with an original $\beta$ less than 1 or a $SCOR$ less than $V\sigma_M$ (Figure 4), the rotation of the iso-value lines due to the reduction in the price of risk combined with their upward translation by the amount $C_1' - C_1$ imply that the value of the firm at the original optimal point $A_1$ is now on a lower iso-value line. The new optimal point $A_2$ which represents a larger $SCOR$ and a larger $E$ may be above or below the iso-value line $C_1'B$ depending on the curvature of the transformation possibility frontier $H(E, SCOR)$. The case illustrated in Figure 4 corresponds to the case where the increase in the risk-free rate, while inducing changes in VAM activities that generate increases in both the expected value and scaled correlation value of the firm's cash flows, causes a drop in the value of the firm.

[Insert Figure 4]

For firms with an original $\beta$ larger than 1 or a $SCOR$ larger than $V\sigma_M$ (Figure 5), the reduction in the price of risk combined with the upward translation of the iso-value lines imply that the value of the firm at the original optimal point $A_1$ is now on a higher iso-value line. The new optimal point $A_2$ is then necessarily above the iso-value line $C_1'B$ indicating that for those firms, the increase in the risk-free rate, while inducing as before changes in the mix of VAM activities that generate increases in both the expected value and scaled correlation value of the firm's cash flows, causes an increase in the value of the firm.

[Insert Figure 5]

As a result,

> **Proposition 4:** An increase in the risk-free rate induces an increase in risk taking by the firm as well as an increase in the firm's expected cash flows. The firm's value increases [decreases] if the original $\beta$ is larger [smaller] than 1.

[12]For a firm with $SCOR = V\sigma_M$, we have $E_j = V_j ER_M$ from (8), that is, $\beta = 1$ from (2), and therefore a change in $R_F$ has no effect on its value.

## 5 Independence and Coordination

The developments in the previous section above dealt with VAM activities and therefore with the 'real' side of the firm. We stated that the role of financial risk management was to facilitate the adjustments in the VAM activities, that is, in the portfolio of activities, made necessary by changes in the market parameters such as $E(R_M)$, $\sigma_M$ and $R_F$. Let us see how more precisely.

A firm maximizes its value by having a mix of VAM activities, both POM activities and RRM activities, such that it is on the highest feasible iso-value line, given the firm's available technology. To do so may necessitate some level of coordination between the firm's real risk management and production and operations management. As we will see, operating those two 'real' functions of the firm in silos may not be efficient and the firm may need to design a coordinated strategy of POM and RRM management. The implementation of this coordinated strategy will be facilitated by the financial risk management (FRM) activities.

### 5.1 Coordination to increase $SCOR$ for a given $E$ (creating risk for the firm).

The firm may find itself at a point on its efficiency frontier but to the left of the optimal mix of POM and RRM activities such as point $A_1$ in Figure 6.

[Insert Figure 6]

If the POM manager continues trying to increase $E$ for a given $SCOR$, while its RRM counterpart keeps working to reduce $SCOR$ for a given $E$, the firm as a whole finds itself trying to move in a north west direction that is infeasible. The way out of this efficient but not value maximizing combination of POM and RRM activities is for the RRM manager to let $SCOR$ *increase* above its current level in order to allow the POM manager some leeway to increase $E$. In so doing, the RRM manager must *destroy value* at least momentarily in order to allow an increase in the performance of the POM manager and in the end to increase value.

### 5.2 Coordination to reduce $E$ for a given $SCOR$ (destroying value).

Similarly, the firm may find itself at a point on its efficiency frontier but to the right of the optimal mix of POM and RRM activities such as at point $A_3$ in Figure 6 (for the only purpose of alleviating the presentation, we choose $A_3$ on the same iso-value line as $A_1$). As before, if the POM manager continues trying to increase $E$ for a given $SCOR$, while its RRM counterpart keeps working to reduce $SCOR$ for a given $E$, the firm as a whole finds itself trying to move in a direction that would take it above its efficiency frontier. The way out of this efficient but not value maximizing mix of activities is for the POM manager to let $E$ *decrease* below its current level in order to allow the RRM manager some leeway to reduce $SCOR$. In so doing, the OM manager must *destroy value* at least momentarily in order to allow an increase in the performance of the RRM manager, which in the end will increase the firm's value above its current level.

### 5.3 Flexibility through financial risk management.

So far in the paper we concentrated our efforts on assessing the value associated with operational or real risk management. Financial risk management has been left aside. We address now the role of financial risk management and show how it can contribute to increasing firm value even if financial transactions do not create value per se.

The approach we took to analyze the value of risk management rested on the fact that value is created within the firm by choosing an optimal mix of VAM activities, blending operational or real risk management and operational cash flow management in such a way that a tangency point is reached between the possibility frontier and the market price of risk. As market parameters change, the optimal combination of expected cash flows and scaled correlation must also change. As we just saw, such changes create significant coordination problems between operational risk management and operational cash flow management, as one needs to reduce value in the short term to create enough space for the other to create value afterwards. Coordinating those activities could be so difficult that neither the real risk manager nor the production and operations manager want to be the one responsible for destroying value. Financial risk management allows these two functions to be better coordinated. Let us see how.

Consider again Figure 6. The firm initially has an efficient and optimal mix of RRM and POM at point $A_3$ (the analysis is similar if we take point $A_1$). Following a shock to the market parameters, the new optimal mix would be at point $A_2$. Unfortunately, the POM manager is unwilling to destroy positive net present value projects (moving down) to allow the RRM manager enough room to manoeuvre in order to reach point $A_2$. How can financial risk management help in this process?

Consider in Figure 6 the iso-value line that goes through point $A_3$. This line is, by definition, lower than the iso-value line tangent to the possibility frontier at point $A_2$. What is the economic meaning of these iso-value lines? The slope of these iso-value lines correspond to the price at which one can exchange risk (as measured by the $SCOR$) for expected cash flows on the financial markets. This means that under perfect market conditions, the firm can choose positions on the financial market such that it can reach any point on that line in a manner similar to the portfolio choice of individuals under the two-fund separation approach.

When firms are able to move and reach any point along an iso-value line through financial activities at zero cost, it gives the firm enough flexibility to attain the new optimal allocation point without sacrificing real risk management activities or positive NPV projects. To see why, consider again the firm located at point $A_3$ in Figure 6. This mix of RRM and POM activities is now sub-optimal, but the firm is unable to change its mix of real activities. The financial risk manager can, through financial transactions, move the firm's $(E, SCOR)$ along the iso-value line that goes though point $A_3$, say until point $B$, since financial transactions typically have a zero value. At point $B$, the RRM and the POM managers are given enough room to move to point $A_2$ without going on a path of value destruction. Value is thus created, not through financial risk management activities, but through real or operational activities that would not have been possible if the financial managers had not been able to enter zero value financial operations to generate enough breathing room for the RRM and the POM managers to perform their normal roles.

What is the value of financial risk management then? In and of itself, the value is zero, just as the present value of a forward or a futures contract is zero. The value of financial risk management comes from the fact that it gives the firm sufficient flexibility in its real VAM activities to attain a mix of operational or real risk management and production and operations cash flow management that would have been otherwise impossible or very difficult to achieve.

When there are market imperfections so that the firm is not able to trade $SCOR$ for expected cash flows $E$ at the market price, the analysis still holds, but with a twist. Trading expected cash flows $E$ for $SCOR$ is no longer determined by the iso-value lines, but by a concave function that we discussed earlier. This concave function goes through point $A_3$ and is tangent to the new market price of risk. The remainder of the analysis remains the same as the financial risk manager finds a $B$-like point along this concave function so that the RRM and POM managers find enough room to reach the optimal allocation $A_2$.

The present analysis of the strategic value of financial risk management raises the interesting testable hypothesis that, under certain conditions, the firms that will benefit the most from financial transactions on the derivatives market are those that have a possibility frontier that is the least concave. Indeed, a small change in market parameters will have a greater impact on the optimal mix of activities of low concavity firms. As a result these firms are more likely to use financial transactions to facilitate coordination between their POM and RRM people. At the other end of the spectrum, a firm whose possibility frontier is strongly concave (or even kinked) will not have much use for financial transactions since a change in the market parameters will not have much impact on the optimal combination of $SCOR$ and expected cash flows $E$.

# 6 Other Applications

The approach we develop in this paper can be applied to many situations, including mergers and acquisitions, different business strategies (advertising, R&D, overseas operations), and the mix of insurance contracts and reinsurance.

## 6.1 An application to mergers, acquisitions and divestitures

In Figure 6, points $A_1$ and $A_3$ were located on the firm's efficiency frontier, but they did not represent the value maximizing mix of VAM activities. That combination was given by the point $A_2$. As we discussed in the previous paragraphs, it may be impossible for the firm to move from points $A_1$ and $A_3$ to point $A_2$ if coordination between the POM and RRM functions within the firm is difficult if not impossible. One reason may be that, in the short run, value needs to be destroyed by one of the functions to give the other function some leeway. It may be hard to convince anyone that destroying value creates value.

If coordination is too difficult, it may be a good strategy for the firm to change its possibility frontier by either acquiring a new business or merge with another firm in order to give its managers some room to reach an optimal point. Suppose that before the merger, the firm has a VAM combination at point $A_2$ in Figure 7. Point $A_2$ is efficient, but not optimal. It would be best for the POM function to destroy some positive net present value projects to allow the RRM function some leeway in order to create more value than what was destroyed. If it is impossible to convince the POM function to destroy value, it may be a clever strategy to change the possibility frontier by acquiring a new business. Suppose that the new business changes the efficiency frontier of the firm through a translation to the north east, as in Figure 7. The optimal efficient point along the new possibility frontier is given by point $A_3$. Point $A_3$ is attainable from point $A_2$ since point $A_3$ lies to the north west of point $A_2$.

The change in value of the firm through the acquisition is then given by the difference in the iso-value lines $C_3A_3$ and $C_2A_2$. This difference can be decomposed into two terms: the value of the acquired business, $C_3A_3 - C_1A_1$, and the gains in synergy to the acquiring firm, $C_1A_1 - C_2A_2$. This merger (or acquisition) creates value for the firm by allowing the RRM and POM function of the firm to reach a better allocation than before.

[Insert Figure 7]

All mergers may not create value, however, if it does not create enough room to maneuver for the firm's POM and RRM functions. For example, in Figure 8, the firm's current VAM mix is given by point $A_2$ while the value maximizing mix would be at point $A_1$. If the firm acquires a new business so that the optimal allocation on the new efficient frontier is given by $A_3$, such a point is not attainable unless the RRM function accepts to destroy value before the POM function is able to increase firm value.

In the case of Figure 8, the merger may be destroying value for the acquiring firm. The fair price of the acquired business is given, as in the previous example, by the difference between the iso-value lines that goes through $C_3A_3$ and the iso-value line that goes through $C_1A_1$. If the acquiring firm is not able to move its VAM mix to an iso-value line higher than the current iso-value line that goes through $C_2A_2$ by at least an amount $C_3A_3 - C_1A_1$, then the acquiring firm is over paying for the acquired firm and thus value is destroyed by the merger/acquisition.

[Insert Figure 8]

The acquisition of a new business may then be value creating or value destroying depending on the impact of the new business on the acquiring firm's efficiency frontier and on the relationship between the optimal point on the new efficiency frontier ($A_3$ in the two figures) and the current point on the pre-acquisition efficiency frontier ($A_2$ in the two figures).

### 6.2 Value maximizing business strategies

At the optimum, any value maximizing business strategy $a$ must satisfy:

$$-\left.\frac{\partial E_j / \partial a}{\partial SCOR\left(cf_j, R_i\right) / \partial a}\right|_{H(E, SCOR_1, \ldots, SCOR_N)=0} = \frac{E\left(R_i\right) - R_F}{\sigma_i} \tag{16}$$

for all risk factors $i = 1, ..., N$.

### 6.2.1 Advertising and R&D programs

Schramm and Sherman (1974) examine a firm's decision to invest in advertising and in research and development. They argue that these types of investment can be used to stabilize the volatility of a firm's earnings. Accordingly, advertising and R&D expenditures should be higher when the economy is doing good, and lower when the economy is doing poorly.

In the single risk factor context, advertising in the sense of Schramm and Sherman (1974) leads to both a reduction in the scaled correlation of the firm's cash flows with the market returns and a reduction in the firm's expected cash flows. This would mean a shift to the left or south west on the firm's transformation frontier. From the theory we developed, this change would be desirable if for instance $E(R_M)$ has increased or $\sigma_M$ has decreased, both indicators that the economy is doing well.

In general, however, advertising and R&D investments may not always reduce the volatility of the firm's earnings nor reduce their expected value. Indeed, a change in $E(R_M)$ may not lead to a change in the amount invested in advertising and in R&D programs, but in the type of advertising and R&D program that becomes funded. For example, when $E(R_M)$ increases so that the price of risk in the economy increases, we know that the firm should invest in activities that reduce both its risk and its return. This may be achieved by an advertising campaign that is geared toward an older segment of the population, a segment whose tastes are more stable, providing lower risk for the product but also lower rewards as well. Alternatively, when the price of risk falls following an increase in $\sigma_M$, the firm should invest in advertising that targets the young, which ceteris paribus represents a segment of the population whose tastes are likely to be more volatile but that offers greater potential rewards.

A similar story can be said about investment in R&D programs. Investment into radical new research is more likely to be associated with higher expected earnings but also much greater risk. This type of investment should occur or increase when the firm's optimal mix of VAM activities should move to the right on the transformation possibility frontier, hence when the price of risk has decreased. In contrast, R&D programs that are safer would be put in place when the price of risk has increased.

### 6.2.2 Expanding in overseas markets

Expanding in overseas markets, the method used to expand in those markets and the choice of the overseas markets are also ways to shift the company's risk and return position on the transformation possibility frontier. As the price of risk increases, a firm will invest in a foreign country whose economy has a lower risk than the domestic economy, thus shifting the firm's position to the left. Another possibility is that the company will try to exit foreign markets that have become too risky given the new market price of risk. The same increase in the price of risk may also induce the firm to use alliances and joint ventures to enter into a new country instead of setting up a new subsidiary. Joint ventures are less risky than setting up new companies in the new markets but the rewards must be shared.

### 6.3 Insurance: deductible, coinsurance and reinsurance

Turning now to the case of an insurance company, we can also make predictions regarding the type of insurance product that will be offered on the market and regarding the demand for reinsurance. *Ceteris paribus*, an insurance company that needs to reduce its risk and its expected return to maximize its market value will be inclined to offer contracts where the policyholder is more financially involved. This means that the insurance company will be more likely to offer contracts where the deductible and/or the co-payment of the insured are larger. By doing so, the firm is less at risk but its earnings are smaller.

On the reinsurance market, the same company that wants to reduce its risk and return will try to shift to reinsurers a larger proportion of its portfolio of insurance policies. By doing so, the insurance company must pay a higher premium, thus reducing its expected cash flows but its risk has been lowered accordingly. What would induce a higher demand for reinsurance products? According to our framework of analysis, insurers will unambiguously seek more reinsurance when

- either the expected return on the market portfolio $E(R_M)$ increases or the the volatility of the market return decreases (in Figure 3, going from $A_1$ to $A_2$);
- the risk-free rate decreases (in Figures 4 and 5, going from $A_2$ to $A_1$), independently of the insurer's $\beta$.

## 7 An Intertemporal Framework

Until now, we have sidestepped the problem of computing the present value of intertemporal cash flows by assuming a flat term structure and a constant risk measure over time. In our simple framework the transformation possibility frontier did not change over time. In a more realistic setting where risk and returns change over time, we need to compute at each point in time, say $t$, an efficient frontier $H_t(E_t, SCOR_t) = 0$, where $E_t$ and $SCOR_t$ group all the conditional expected values and scaled correlations. The extension to an intertemporal framework can be set in an Arrow-Debreu type economy or in a world with a general stochastic discount factor. In such intertemporal extensions, both the price of risk and the price of time will play a role in the marginal trade-offs the firm will engage in, both across states of nature and periods.

In a recent paper, Alexander and Pézier (2003) propose a similar approach to aggregating market and credit risks in large complex financial firms. They identify risk factors that are common to various business activities and account for the dependencies between the various risk factors across business lines to evaluate the aggregate risk of the firm. They set up their factor model in terms of present value of profit and loss over the relevant time horizon. They never mention how to compute the present value but their model implies that the discounting is done with the term structure of interest rates taken as given. A fully integrated intertemporal framework needs to treat together time and risk.

To be as general as possible, we need not specify a linear risk model. We can rely on the existence of a stochastic discount factor, say $m_{t,T}$, which gives the value in $t$ of a cash flow in $T$, in the absence of arbitrage opportunities. The value in $t$ of any project within the firm with associated cash flows $C_{t+1}, \cdots, C_T$ from $t+1$ to $T$ is then given by:

$$P_t = E_t[m_{t,t+1}C_{t+1} + \ldots + m_{t,T}C_T] \tag{17}$$

By the covariance formula, this can be further decomposed as:

$$\begin{aligned} P_t \quad = \quad & E_t[m_{t,t+1}]E_t[C_{t+1}] + Cov_t(m_{t,t+1}C_{t+1}) \\ & + \cdots \\ & + E_t[m_{t,T}]E_t[C_T] + Cov_t(m_{t,T}C_T) \end{aligned} \tag{18}$$

We can group these expressions into two distinct blocks, one for the expectations products, the other for the covariances:

$$P_t = EV_t + COV_t \tag{19}$$

with:

$$
\begin{aligned}
EV_t &= E_t[m_{t,t+1}]E_t[C_{t+1}] + \cdots + E_t[m_{t,T}]E_t[C_T] \\
COV_t &= Cov_t(m_{t,t+1}C_{t+1}) + \cdots + Cov_t(m_{t,T}C_T)
\end{aligned}
\tag{20}
$$

The expectation terms $E_t[m_{t,\tau}]_{\tau=t+1}^{T}$ provide the prices of zero-coupon bonds for the corresponding horizons $\tau = t+1, \cdots, T$. An efficiency frontier can then be defined in terms of $(E_t, COV_t)$ as before, but now the frontier will change at each period depending on the evolution of the term structure of interest rates and of the risk measures embedded in the stochastic discount factors. Since all quantities have been discounted at time $t$ accounting for both the values of time and risk in the cash flows over time and states of nature the iso-value lines will have a slope of one. Of course the analysis of the trade-offs between expected cash flows and risk or between different risks becomes more involved but remains possible once a specific content is given to the stochastic discount factor through a model.

When the stochastic discount factor is modeled as in the CAPM or the multifactor model described in section 2, we saw that the trade-offs can be expressed between expected cash flows and scaled correlations. At the level of generality specified in (17) we cannot obtain a separation of parameters leading to the use of scaled correlations. More structure should be put in the stochastic discount factor to arrive at a similar separation. For example, one can extend the factor model described in section 2 to a dynamic factor model where the betas will change over time, assuming for simplicity that the term structure of interest rates is flat. Different dynamic economic models will imply different frontiers but each firm will likely identify the main factors of risk over which it wants to assess the riskiness of its future cash flows.

Another dynamic consideration relates to the use of real options in the estimation of the firm's transformation frontier. The management of real options is a process aimed at actively reducing exposition to downside risk and promoting exposition to upside opportunities. From the real options viewpoint, projects are not simply sequences of uncertain cash flows over time but rather sets of compound American options. Indeed, managing risks and more generally value creation in a firm requires the identification, creation and management of the real options embedded in the portfolio of potential activities, which define the firm as an economic entity. The contribution of higher level managers to the value of a firm may lie mainly in creating and exercising real options. [13]

[13] As pointed out by *The Economist* (August 12, 1999): "To evaluate potential projects, [$firms$] almost invari-

# 8 Conclusion

The current theoretical and empirical literature on risk management does not integrate the risk management function within the bounds of the corporation. Instead risk management, and especially financial risk management, is viewed as a special purpose function of the firm rather than an integral part of decision making. We deviate from this traditional perception of risk management to make it an integral part of the firm' technology that allows to transform cash flows between states of the world and across time.

To do so, we express the firm's efficient frontier in terms of expected cash flows and risk so that we are able to study more explicitly the role and impact of parameters that affect the market price of risk. Moreover, we are able to characterize the relative impact of each risk factor on the firm's activity mix related to production and operations management and real risk management. In so doing, we presented real risk management as a fundamental function of the firm. Like any other function in a corporation, its goal is to contribute to the increase and maximization of the firm's value within the feasible set of transformation possibilities. In other words, real risk management is an input in the firm's value function, just as labor and capital are inputs in the production function. New insights on the value of real risk management are obtained.

The approach we adopted to study risk management emphasizes two important sets of considerations within the firm. First, there are the relative levels of "independence" and "coordination" which must take place between the firm's real risk management and production and operations management units or functions. Both units seek to increase the value of the firm, but they each have power only over a subset of the possible tools. Second, there is the search for efficiency (being on the frontier of possibilities) and optimality (being at the right point on that frontier) which underlies and determines the observed values of expected cash flows and their risk level. Reaching the possibility frontier and finding the best possible point on the frontier given the market conditions are two different programs in the maximization of the market value of the firm.

The role of financial risk management in this context is fundamentally to facilitate the

ably have to resort to a theory of corporate finance called the 'Capital Asset Pricing Model' (CAPM). Yet real-life managers tend not to like this model, for the simple reason that it ignores the value of real-life managers. So they might welcome some recent academic work. In the ivory tower, they are talking about ditching the CAPM for a rival, called 'real options theory'. Managers are therefore placed at the very core of the use of real options. More fundamentally, the flaw in the CAPM is that it implicitly assumes that when firms buy new assets, they hold these passively for the life of the project."

coordination of decentralized VAM activities between the real risk management function and the production and operations management function. Although such transactions on financial markets generate no value directly, they do generate flexibility and therefore contribute indirectly to the value of the firm. This is a *new and important role* for financial risk management, which is present even in a Modigliani-Miller framework.

The basic idea and the main contribution of our paper is to define a transformation possibility frontier of cash flows between states and time periods, giving rise to an efficient frontier in such a space. This efficient frontier emerges from all feasible production and operations management and real risk management activities and, alongside the production possibility frontier, characterizes the firm as an economic entity. Our approach opens a new avenue to empirical work on the value of risk management which sidesteps the need to test the theories justifying the existence of risk management within a firm. Access to micro data banks on firms could lead to the estimation of risk-reward frontiers, more precisely of frontiers expressed in terms of risk and expected cash flows, as it was done for production frontiers.

## References


[1] Alexander, C. and J. Pézier (2003), "On the Aggregation of Firm-Wide Market and Credit Risk,"ISMA Centre Discussion Papers in Finance 2003-13, University of Reading, UK.

[2] Allayannis, G. and J. Weston (2001), "The Use of Foreign Currency Derivatives and Firm Value,"*Review of Financial Studies* 14, 243-276.

[3] Bessembinder, H. (1991), "Forward Contracts and Firm Value: Investment Incentive and Contracting Effects", *Journal of Financial and Quantitative Analysis* 26, 519-532.

[4] Block, S.B., and T.J. Gallagher (1986), "The Use of Interest rate Futures and Options by Corporate Financial Managers,"*Financial Management* 15, 73-78.

[5] Bodnar, G.M., G.S. Hayt and R.C. Marston (1998), "Wharton 1998 Survey of Risk Management by US Non-Financial Firms,"*Financial Management* 27, 70-91.

[6] Booth, J.R., R.L. Smith and R.W. Stolz (1984), "The Use of Interest Futures by Financial Institutions", *Journal of Financial Economics* 8, 3-29.

[7] Boyer, M. and J. Robert (2005), "Organizational Inertia and Dynamic Incentives," *Journal of Economic Behavior and Organization* (forthcoming).

[8] Boyer, M.M. (2004), "On the Use of Hierarchies to Complete Contracts when Players Have Limited Abilities," CIRANO Working Paper, 2004s-41.

[9] Breeden, D., and S. Vishwanathan (1996), "Why Do Firms Hedge? An Asymmetric Information Model,"Duke University Working paper.

[10] Chacko, G., P. Tufano and G. Verter (2001), "Cephalon, Inc. Taking Risk Management Theory Seriously", *Journal of Financial Economics* 60, 449-485.

[11] Chowdhry, Bhagwan, and Jonathon Howe (1999), "Corporate Risk Management for Multinational Corporations: Financial and Operational Hedging Policies", *European Finance Review* 2, 229-246.

[12] Cummins, J.D. (1976), "Risk Management and the Theory of the Firm", *Journal of Risk and Insurance* 43, 587-609.

[13] DeMarzo, P. and D. Duffie (1993), "Corporate Incentives for Hedging and Hedge Accounting," *Journal of Applied Corporate Finance* 6, 4-15.

[14] Doherty, N.A. (1997), "Corporate Insurance: Competition from Capital Markets and Financial Institutions", *Assurances* 65, 63-94.

[15] Dolde, W. (1993), "The Trajectory of Corporate Financial Risk Management," *Journal of Applied Corporate Finance* 6, 33-41.

[16] Fama, E.F. and M.H. Miller (1972), *The Theory of Finance*, Hinsdale: Dryden Press.

[17] Froot, K., D. Scharfstein and J. Stein (1993), "Risk Management: Coordinating Corporate Investment and Financing Policies," *Journal of Finance* 48, 1629-1658.

[18] Geczy, C., B. Minton and C. Schrand (1997), "Why Firms Use Currency Derivatives," *Journal of Finance* 52, 1323-1354.

[19] Graham, J.R. and C.R. Harvey (2001), "The Theory and Practice of Corporate Finance: Evidence from the Field," *Journal of Financial Economics* 60, 187-243.

[20] Graham, J.R. and D.A. Rogers (2002), "Do Firms Hedge in Response to Tax Incentives?," *Journal of Finance* 57, 815-839.

[21] Graham, J.R. (2003), "Taxes and Corporate Finance: A Review," *The Review of Financial Studies* 16, 1075-1129.

[22] Güntay, L., N. Prabhala and H. Unal (2003), "Callable Bonds, Interest-Rate Risk, and the Supply Side of Hedging," *Journal of Finance* (forthcoming).

[23] Hannan, M.T. and J. Freeman (1984), "Structural Inertia and Organizational Change," *American Sociological Review* 49, 149-164.

[24] Haushalter, D. (2000), "Financing Policy, Basic Risk, and Corporate Hedging: Evidence from Oil and Gas Producers," *Journal of Finance* 55, 107-152.

[25] Holton, G.A. (2004), "A New Position on Risk," *Futures and Options World*, February 44-45.

[26] Jagannathan, R. and T. Ma (2003), "Risk Reduction in Large Portfolios: Why Imposing the Wrong Constraints Helps," *Journal of Finance* 58(4), 1651-1685.

[27] Lessard, D. (1991), "Global Competition and Corporate Finance in the late 1990's," *Journal of Applied Corporate Finance* 3, 59-72.

[28] MacKay, P. and S. Moeller (2003), "The Value of Risk Management," *Mimeograph*, Southern Methodist University.

[29] Main, B. (1983), "Corporate Insurance Purchases and Taxes," *Journal of Risk and Insurance* 50, 197-223.

[30] Mayers, D. and C.W. Smith Jr. (1982), "On the Corporate Demand for Insurance", *Journal of Business* 55, 281-296.

[31] Mayers, D. and C.W. Smith Jr. (1987), "Corporate Insurance and the Under Investment Problem", *Journal of Risk and Insurance* 54, 45-54.

[32] Mayers, D. and C.W. Smith Jr. (1990), "On the Corporate Demand for Insurance: Evidence from the Reinsurance Market", *Journal of Business* 63, 19-40.

[33] Mehr, R.I. and S.W. Forbes (1973), "The Risk Management Decision in the Total Business Setting," *Journal of Risk and Insurance* 40, 389-401.

[34] Michaud, R. (1998), *Efficient Asset Management, A Practical Guide to Stock Portfolio Optimization and Asset Allocation*, HBS Press.

[35] Myers, S.C. and N.S. Majluf (1984), "Corporate Financing and Investment Decisions when Firms Have Information that Investors Do Not Have", *Journal of Financial Economics* 13, 187-221.

[36] Nance, D.R., C.W. Smith and C.W. Smithson (1993), "On the Determinants if Corporate Hedging", *Journal of Finance* 48, 267-284.

[37] Rawls, S.W., and C.W. Smithson (1990), "Strategic Risk Management," *Continental Bank Journal of Applied Corporate Finance* 2, 6-18.

[38] Schramm, R. and R. Sherman (1974), "Profit Risk Management and the Theory of the Firm," *Southern Economic Journal* 40, 353-363.

[39] Smith, C.W. (1995), "Corporate Risk Management: Theory and Practice," *Journal of Derivatives* 2, 21-30.

[40] Smith, C.W. and R. Stulz (1985), "The Determinants of Firms' Hedging Policies," *Journal of Financial and Quantitative Analysis* 20, 391-405.

[41] Stulz, R.M. (1996), "Rethinking Risk Management", *Journal of Applied Corporate Finance* 9, 8-24.

[42] Stulz, R.M. (2004), *Risk Management and Derivatives*, Thomson South-Western Publishers.

[43] Tufano, P. (1996), "Who Manages Risk? An Empirical Examination of Risk Management Practices in the Gold Mining Industry," *Journal of Finance* 51, 1097-1137.

[44] Williamson, O. (1967). "Hierarchical Control and Optimum Firm Size," *Journal of Political Economy*, 75: 123-138.

**FIGURE 0**

**The structure of the firm**

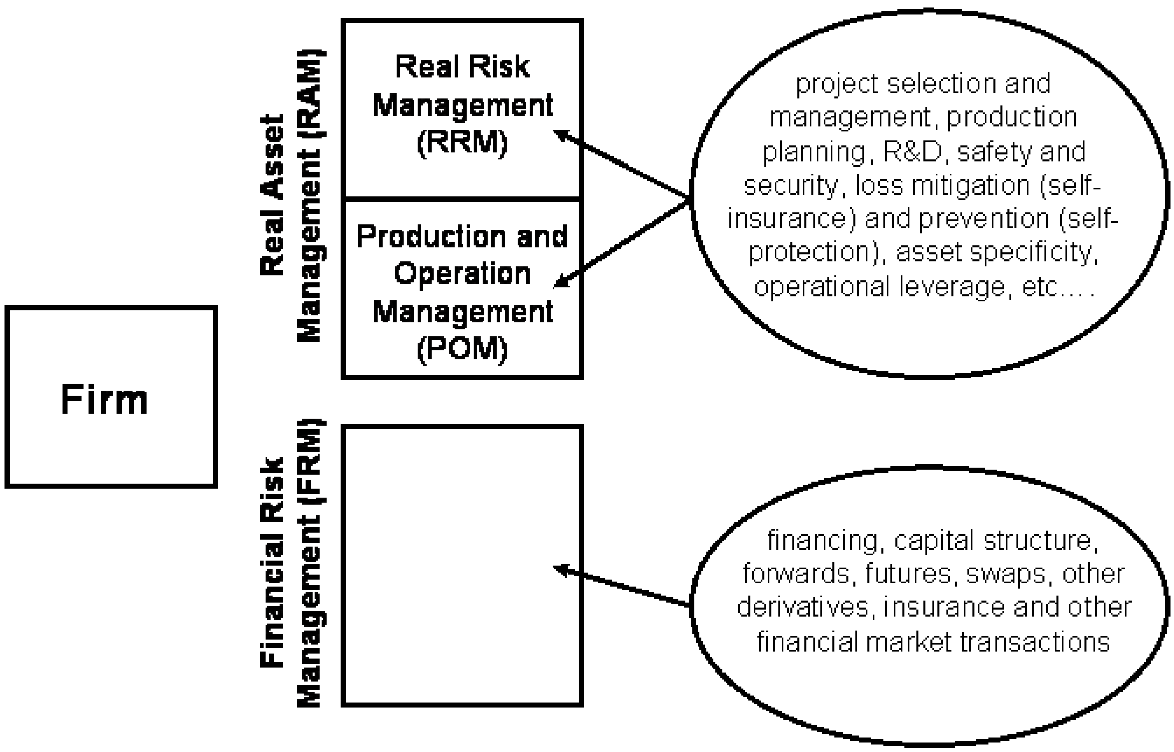

**FIGURE 1**
**Cash Flows Transformation Possibility Frontier**

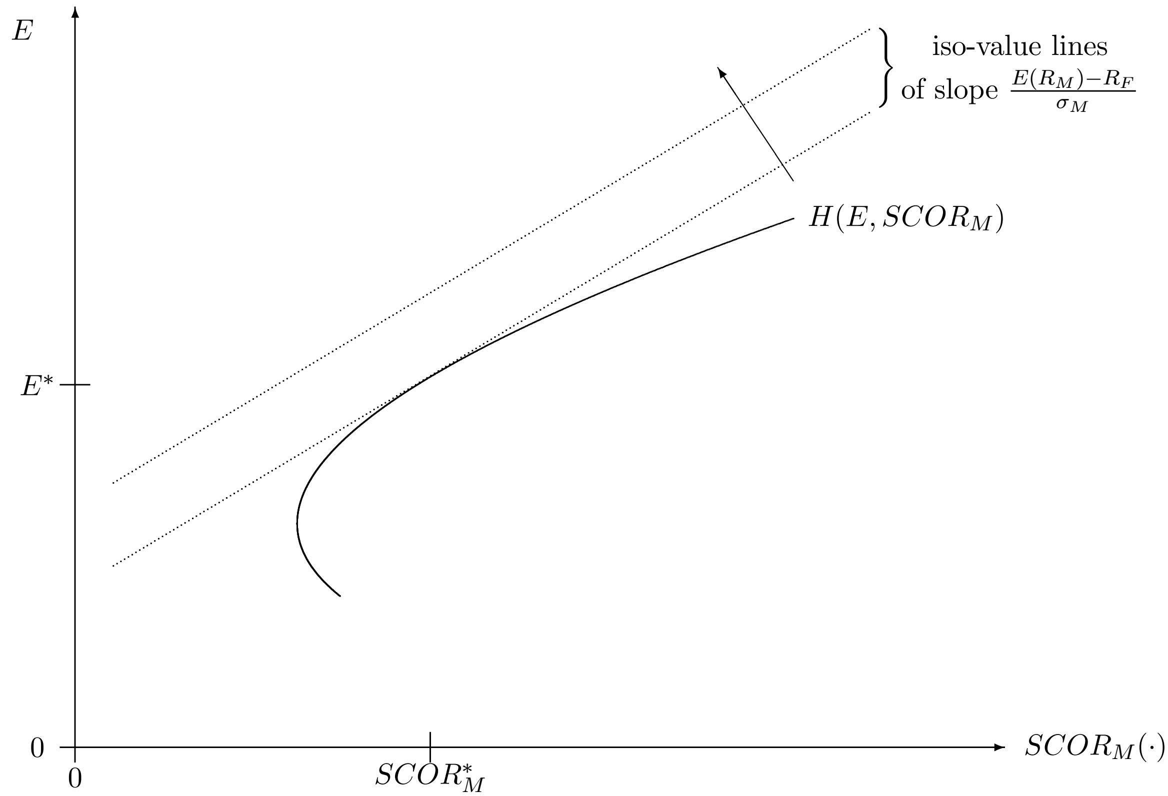

**FIGURE 2**
**Value Maximization**

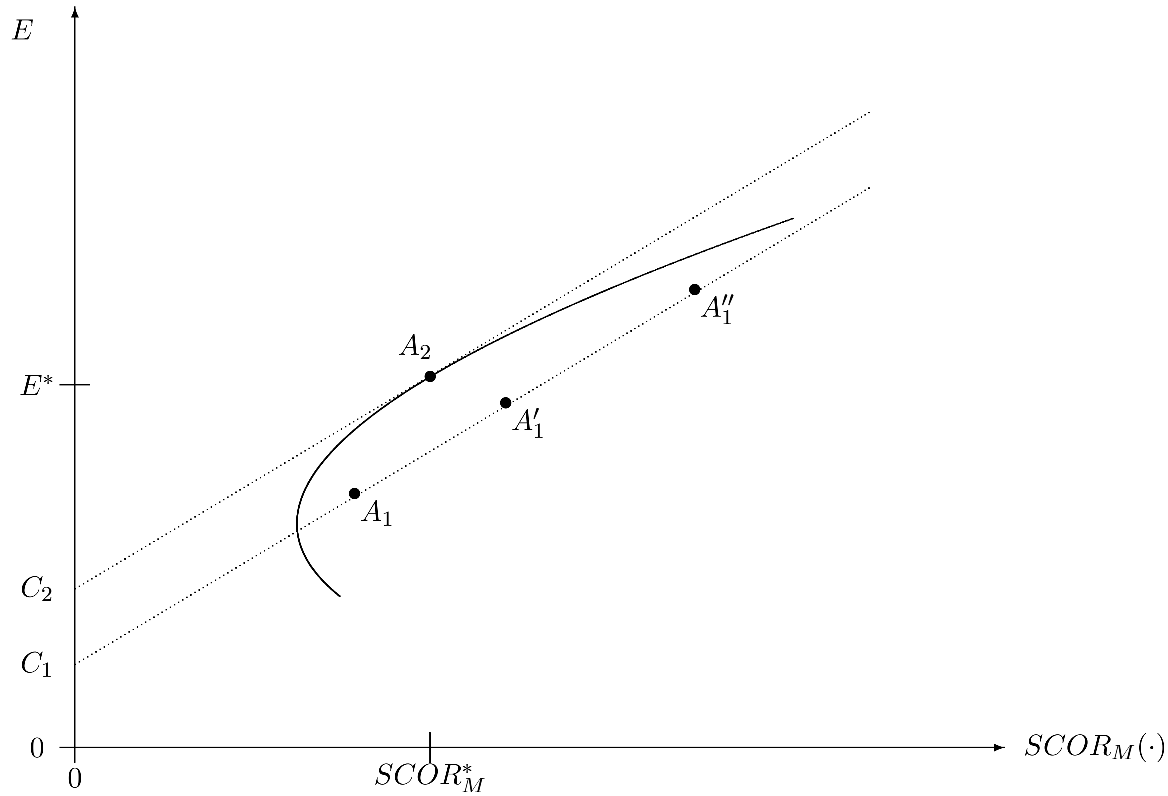

**FIGURE 3**
**An increase in market return $E(R_M)$**
**or a decrease in market volatility $\sigma_M$**

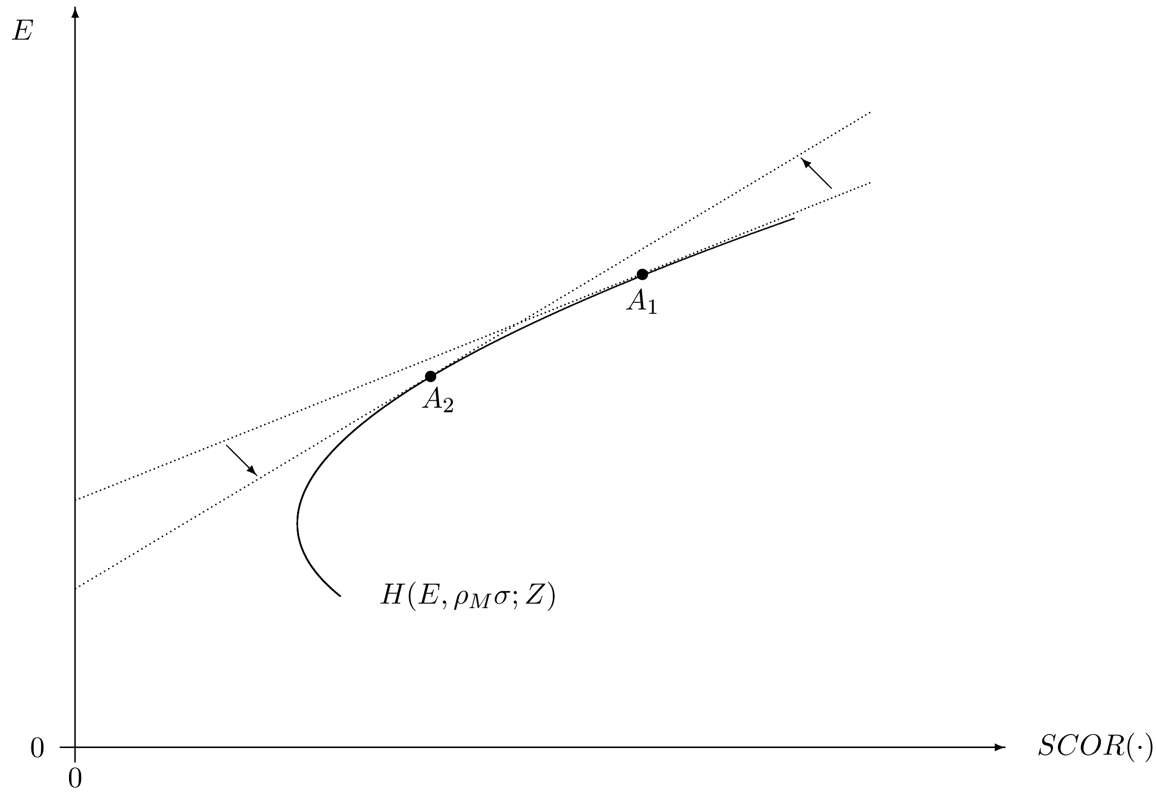

**FIGURE 4**
**Increase in risk-free rate $R_F$**
**for an original $\beta$ smaller than 1 ($SCOR < V\sigma_M$)**

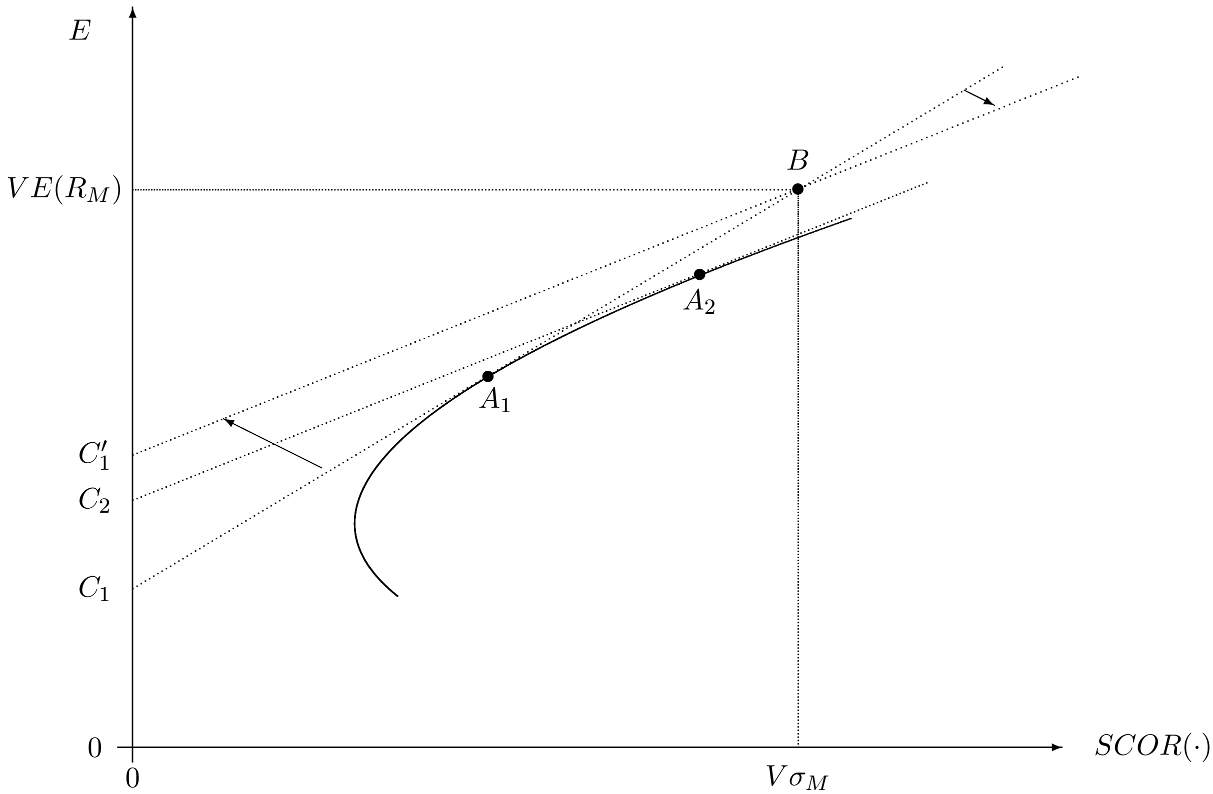

**FIGURE 5**
**Change in risk-free rate $R_F$**
**for an original $\beta$ larger than 1 ($SCOR > V\sigma_M$)**

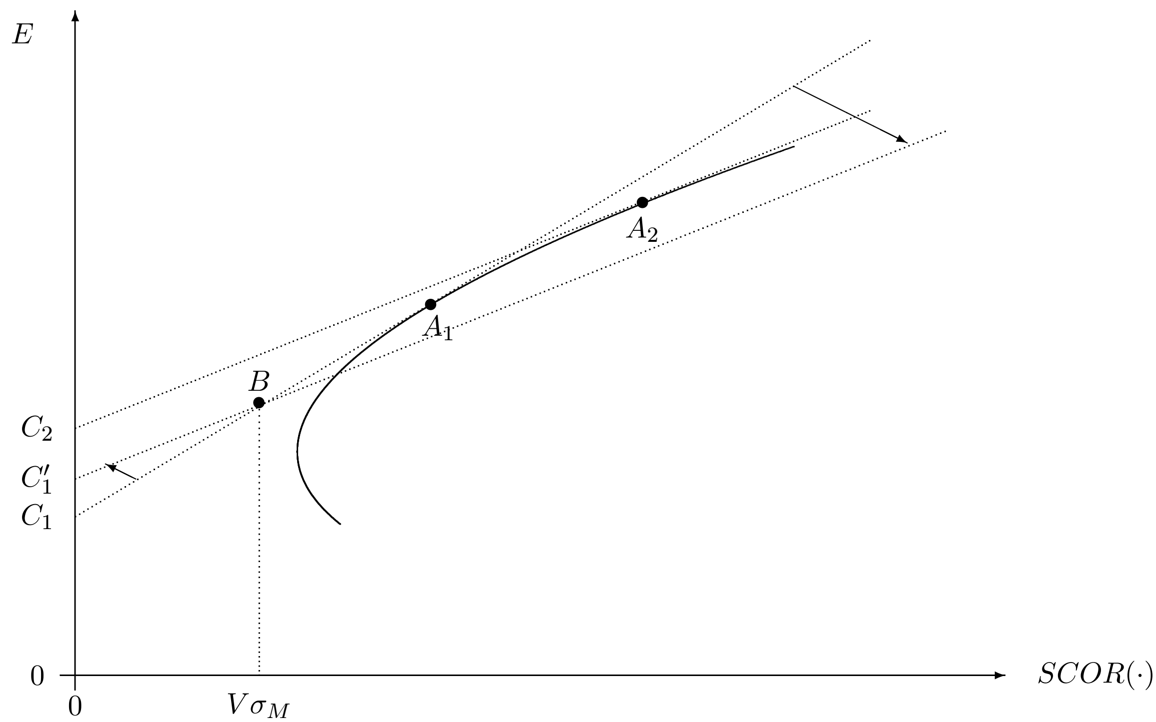

**FIGURE 6**
**Independence and coordination**

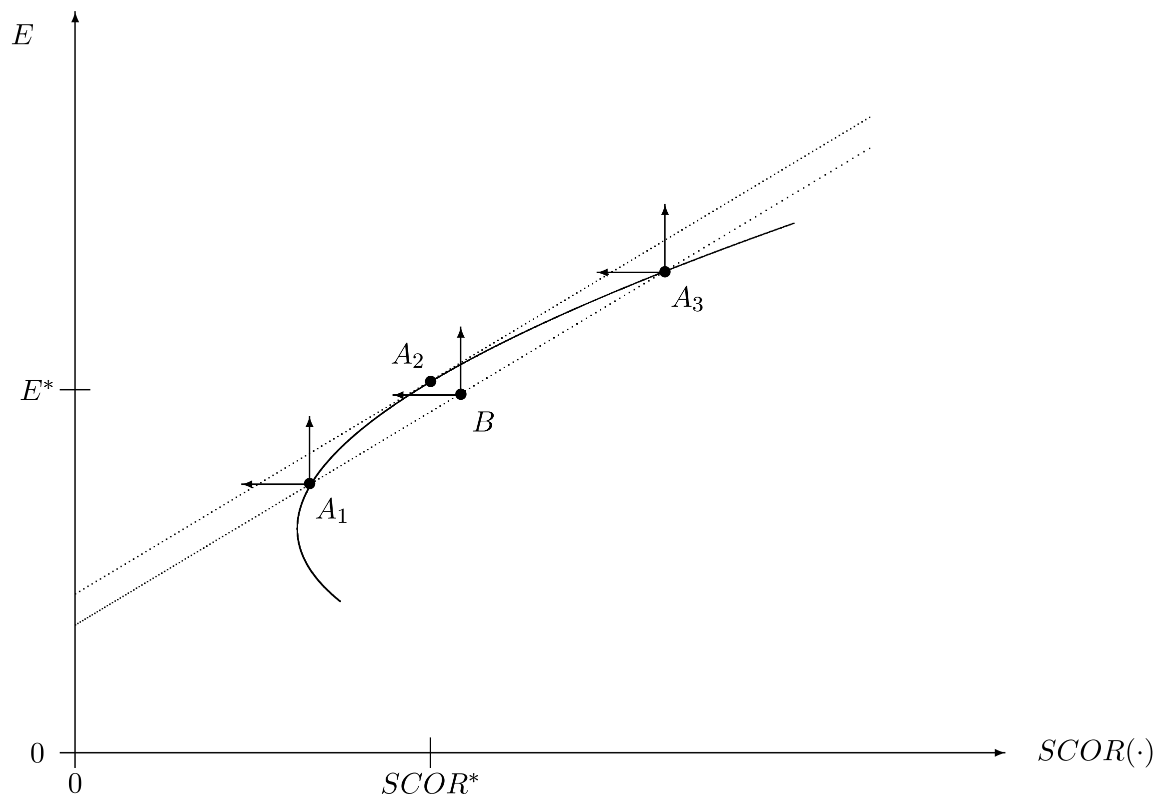

**FIGURE 7**
**Merger and acquisition: value creation**

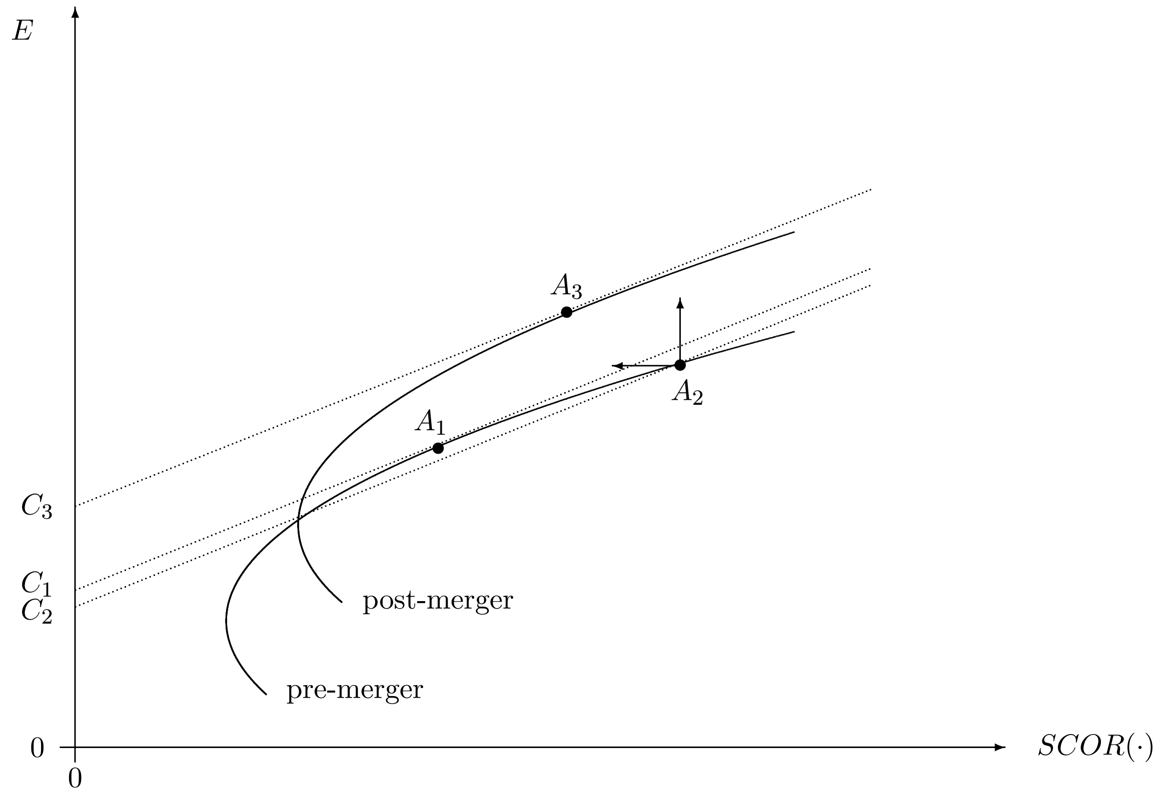

**FIGURE 8**
**Merger and acquisition: possible value destruction**