

**Operational Hedging:
A Review with Discussion**

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Abstract

Motivated by the increasing prevalence of operational hedging in corporate-level risk management programs, this paper provides an extensive overview and synthesis of the existing literature on operational hedging. In particular, we focus on the treatment of operational hedging in the operations management literature. We then explore how the concept of operational hedging is studied in the fields of finance, strategy and international business. Finally, we discuss and critique the approaches adopted in the operations management literature in the context of the broader literature on the topic.

Keywords: Operational Hedging, Risk Management, Operational Flexibility

1. INTRODUCTION

Corporations are faced with a wide variety of risks such as supply-demand coordination risks, exchange rate risks, political risks and disruption risks. Corporate risk management programs aim to systematically manage such risk exposures so as to increase firm value. In the aftermath of serious financial losses by prominent firms and local governments due to inappropriate risk management programs based on financial derivatives, a survey in *The Economist* (1996, p.18) focuses on “other ways of spreading risk in non-financial companies.” In particular, the article discusses “natural hedges” such as financing an operation in local currency, and “operational hedging” such as relocating production facilities to get a better match of costs to revenues. As noted in a recent series of articles in the *Financial Times* on corporate risk management, “In the past few years, car makers have also been addressing manufacturing risks by reorganizing large chunks of their business to offload risk to suppliers” (*Financial Times* 2003, p.4). Another example is Microsoft’s reliance on temporary workers: “We [Microsoft] count on them [temporary workers] to do a lot of important work for us. We use them to provide us with flexibility to deal with uncertainty” (*Los Angeles Times* 1997, p.D1 as quoted by Meulbroek 2002b). Such operational flexibility is important for the firm to respond to unexpected shocks in demand, technology or regulation (Meulbroek 2002b). Motivated by the increasing prevalence of operational hedging in corporate-level risk management programs, we provide an extensive overview and synthesis of the existing literature on operational hedging. We start by discussing the rationale behind corporate risk management and tools available for this purpose.

The main objective behind corporate risk management programs is to increase shareholder wealth by enhancing firm value through the management of risk exposures. Paradoxically, building on the seminal work of Modigliani and Miller (1958), classical finance theory asserts that under perfect and complete markets, corporate risk management programs do not add any value: Under these assumptions, the benefits of any risk management activity by firms can be reproduced by shareholders through asset diversification. In other words, risk management cannot create value by undertaking activities that investors can do equally well.

However, there are several rationales motivating corporate-level risk management

programs. Market imperfections exist that make volatility costly to firms and that are effectively managed only through firms themselves (Fite and Pflleiderer 1995). The corporate finance literature identifies different market imperfections as reasons for the existence of firm-level risk management: financial distress and bankruptcy costs (Smith and Stulz 1985), corporate taxes (Smith and Stulz 1985), more costly external financing (Froot et al. 1993), and agency problems such as managerial risk aversion (Smith and Stulz 1985) and information asymmetry between managers and shareholders (DeMarzo and Duffie 1995). Aside from these market imperfections, another reason for corporate-level risk management programs is that shareholders hardly hold well-diversified portfolios (for as in the case of family-owned firms). Even if they are well-diversified, shareholders might still prefer corporations to manage their risk exposures in order not to reestablish their portfolios very frequently (Fite and Pflleiderer 1995).

The first step in any risk management activity is the identification and assessment of risk exposure (Bodie and Merton 1998). Firms are exposed to a portfolio of risks, some of which are firm-specific whereas the rest are inherent to capital markets and common to all firms in the economy (market risks). Some of these risks are contingent on *asset prices* such as interest rates, exchange rates and commodity prices. However, there are other types of risks that mainly stem from *firm operations*. Kleindorfer and Van Wassenhove (2003) consider risk management in the global supply chain and discuss two broad categories of risk: disruption risk due to accidental or purposeful triggers (e.g. earthquakes, terrorism) and supply-demand coordination risk (e.g. order cancellation, supplier default). According to Billington et al. (2003), uncertainties about demand for products and supply of key inputs are the greatest risks of most manufacturers. These risks create a supply-demand mismatch that results in financial losses.

After determining their risk portfolio, firms have a significant number of tools to put to use in managing their exposures. Taking short or long positions in financial derivatives (forwards, futures, options, swaps etc.), carrying large cash balances, adopting conservative financial policies (Tufano 1996) or holding foreign denominated debt (Geczy et al. 1997) are financial means for risk management. In particular, financial derivatives, tailored contracts written over asset prices such as interest rates, exchange rates and commodity prices, which provide risk transfer between the transacting parties,

have been utilized extensively at the firm level through well-developed financial markets for a long time.

Although such financial tools are appropriate for firms that have risk exposures contingent on asset prices, other types of risks stemming from firm operations cannot be managed through the use of financial contracts (Guay and Kothari 2003). In addition to contractual agreements between parties (Cachon 2002), firms engage in operational activities to manage such risk exposures. Investments having real option features are the prevalent instruments used for this purpose. Real options are “opportunities to delay and adjust investments and operating decisions over time in response to resolution of uncertainty” (Triantis 2000). The value of real options is driven not only by timing (through the postponement of operating decisions) but also by scope (by providing a set of alternatives instead of a single choice) (Billington et al. 2003).

Real options are referred to as *operational hedging mechanisms* in the operations management literature. Operational hedging has been studied in a variety of fields - operations management, finance, strategy and international business. In all fields, operational hedging is discussed in conjunction with financial hedging, and mostly analyzed in a multinational context. The existence of risks that can only be managed operationally (Triantis 2000) means that operational hedging constitutes an important part of firm-level risk management programs: Empirical investigations (Allayannis et al. 2001, Pantzalis et al. 2001) clearly demonstrate that firms do use operational hedges in managing their risks.

Let us demonstrate the role of operational hedging by an example in a multinational framework. A manufacturing firm with production and sales operations in foreign countries is exposed to demand and exchange rate risks. The firm can use financial tools (e.g. forwards) to manage its exposure to exchange rate risks, but these tools are not effective in altering the demand risk exposure. However, postponing the production decision until after more accurate information about demand is acquired buffers against demand uncertainty by better matching supply and demand. This operational decision (postponement), used as a risk hedging device, is an operational hedge of the multinational firm.

Although there are similarities in forms of operational hedging across different

academic fields, as we discuss below, we observe that there is no consistent framework on operational hedging that spans these fields. In this paper, we review and provide a synthesis of existing literature on operational hedging from the operations management, finance, strategy and international business fields, and discuss and critique the operational hedging framework developed in operations management in the light of the broader literature.

Two related definitions of operational hedging have been proposed in the operations management literature. We state and discuss these definitions in Section 2.1 where we explore how operational hedging is addressed in the operations management literature. Sections 2.2 and 2.3 do the same for the finance, and strategy and international business literatures, respectively. Thus, Section 2 provides an extensive overview of the forms of operational hedging that appear in the operations management, finance, strategy and international business literatures, which has not appeared in the literature to date.

Section 3 identifies some limitations and inconsistencies of the definitions of operational hedging in operations management, in the light of the broader literature on the topic. In particular, we demonstrate that real options are not the only means of operational hedging, but that there are additional operational tools that firms can employ to mitigate their risks (Section 3.1). In addition, based on the hedging rationale put forward in the finance literature, we argue that real options should not always be considered as operational hedges (Section 3.2). Finally, we show that real options do not necessarily satisfy the type of risk reductions that form the basis of the existing definitions (Section 3.3). Section 4 concludes the paper.

2. LITERATURE REVIEW

In this section, we review the literature on operational hedging in operations management, finance, strategy and international business. We only concentrate on operational hedging and therefore do not cover other literature on risk management. In addition, we do not consider contractual agreements for transferring risks (Spinler et al. 2002) as operational hedges, but focus only on operational means of hedging. Finally, we do not review recent research in operations management that incorporates risk aversion or real option valuation methods and refer interested readers to Van Mieghem (2003) and

Smith and McCardle (1998) and the references therein, respectively, for reviews of these literatures.

2.1 Operations Management

In operations management, there are two streams of research originating from two separate, but conceptually similar, definitions of operational hedging. The *first definition*, as introduced by Huchzermeier (1991) and quoted in Ding and Kouvelis (2001, p.2), states that “Operational hedging strategies ... can be viewed as real (compound) options that are exercised in response to demand, price and exchange rate contingencies faced by firms in a global supply chain context.” These options are supply chain network options that are derived from the global coordination of sourcing and/or production decisions. Postponing the logistics decision (Ding and Kouvelis 2001), switching production and sourcing strategies contingent on demand and exchange rate uncertainties (Cohen and Huchzermeier 1999), switching among supply chain network structures (Huchzermeier and Cohen 1996), holding excess capacity (Cohen and Huchzemeier 1999) and delaying the final commitment of capacity investments are means of operational hedging. These real options, used as operational hedges, are argued to mitigate the risk exposure in the long run by reducing the downside risk (Cohen and Huchzermeier 1999).

All of the above real options are forms of operational flexibility, which is created through the deployment of excess capacity and/or stochastic recourse. As defined in Cohen and Huchzermeier (1999), operational flexibility is a firm’s ability to anticipate and respond to changes in market conditions flexibly by means of the firm’s operations. By exercising these options, multinational exploit the volatility in the environment. To explain what this means, consider the example given in Cohen and Huchzermeier (1999): A multinational firm determines the location of production facilities (network structure) but postpones the production quantity decision (logistics decision) until after seeing the demand and exchange rate realizations. Without the postponement option, the firm would choose a given network structure and production quantities and obtain a level of profits. When it has the option to postpone the logistics decision, on the other hand, the firm may choose a different network structure with more facilities (excess capacity). The authors show that the value of the firm may then increase. In other words, real options have value-enhancing capabilities under uncertainty. Note that the postponement option would

not have created any value if demand and exchange rate were deterministic. For this reason, the value-enhancing feature of real options under uncertainty is called “exploiting uncertainty.” This value increase is achieved without necessarily reducing the volatility of the firm’s cash flows. In fact, even in a risk-neutral setting, where volatility of cash flows is not of concern, it may be beneficial to use real options due to their value-enhancing capabilities (Ding and Kouvelis 2001).

Huchzermeier and Cohen (1996) analyze operational flexibility, which they define as the ability to switch among different global manufacturing strategy options. Global manufacturing strategy options are created by combining product options (that introduce international supply flexibility) and supply chain network options (that introduce manufacturing flexibility through production capacity and supply chain linkage choices). The authors argue that with operational flexibility, the volatility of firms’ cash-flows is not eliminated but exploited, and that this form of operational hedging utilizes the global supply chain network design to mitigate against exchange rate exposure, increasing the value of the firm and decreasing its downside risk.

Cohen and Huchzemeier (1999) illustrate how the deployment of excess capacity can be a source of operational flexibility in global supply chains. They argue that investing in capacity in excess of the aggregate demand forecast provides flexibility in coping with demand uncertainties. Additionally, they focus on the option to postpone the commitment of resources (stochastic recourse) together with the option to switch among different production locations. Through stochastic recourse, the firm discovers the minimum-cost production location depending on exchange rate realizations. Additionally, excess capacity enables the firm to produce more in that location, providing a value-enhancing opportunity in addition to reducing its downside risks.

Postponing the logistics decision is examined by Ding and Kouvelis (2001) in a two-stage, single-period model. A multinational firm producing domestically and selling only in a foreign market is exposed to demand and exchange rate risks. In the first stage, the firm commits to the production/capacity level taking into account demand and exchange rate uncertainties. In the second stage, after all the uncertainty is resolved, the firm decides how much to allocate from its domestic capacity to the foreign market. The postponement of the allocation decision until after seeing demand and exchange rate

realizations is a real option and constitutes the firm's operational hedging strategy. The authors demonstrate that the allocation option increases the expected utility of both risk-averse and risk-neutral decision makers.

The *second definition* of operational hedging is found in Van Mieghem (2003). Without referring to real options, but making an analogy with its financial counterpart, financial hedging, Van Mieghem defines operational hedging as “mitigating risk by *counterbalancing actions* in a processing network that do not involve financial instruments.” He lists dual-sourcing, component commonality, having the option to run overtime, dynamic substitution, routing, transshipping, or shifting processing among different types of capital, locations or subcontractors, holding safety stocks and purchasing warranty guarantees operational hedging strategies.

We make several observations concerning this definition. One of the main contributions of this definition is the observation that operational hedging can be employed in the absence of tradable risks, particularly exchange rate risk – as we discuss later, all the other academic fields mostly consider operational hedging in an exchange rate framework. Again departing from the literature, Van Mieghem does not consider any particular risk measure to formalize the effect of operational hedging in terms of risk mitigation. In addition, the term “counterbalancing actions” is not formalized: criteria to determine whether given actions are counterbalancing are not developed. In our understanding, this term corresponds to investing in more than one resource, or “betting on two horses” (conversation with the author), that is, investing in operational flexibility, similar to the former definition of operational hedging. Observe that, although not explicitly articulated, all the proposed strategies can be viewed as real options. The real option values of these strategies are driven through either timing (postponement of operational decisions) or scope (through providing a set of alternatives instead of a single choice), if not both. Finally, as with real options, counterbalancing actions described by Van Mieghem have a value-enhancing capability and increase expected profit in a risk-neutral setting. This is demonstrated on a two-product, two-stage production system where capacity imbalance is the operational hedging strategy (Harrison and Van Mieghem 1999, Van Mieghem 2003). These papers argue that by purposely unbalancing the capacity vector, i.e. having safety capacity (in excess of the capacity that would be

optimal in the deterministic case), firms can hedge against demand uncertainty and increase expected profit. Counterbalancing actions, taken in such a way as to maximize expected profit for a risk-neutral decision maker, are called operational hedges.

2.2 Finance

The finance literature has used the term “operational hedging” in the last decade with increasing frequency. It is always discussed in conjunction with its financial counterpart, financial hedging. In the finance literature, operational hedging is the course of action that hedges the firm’s risk exposure by means of non-financial instruments, particularly through operational activities.

Similar to the operations management literature, operational flexibility is the major operational hedging strategy discussed in the finance literature. Finance research underlines the value-enhancing capability of this kind of flexibility by referring to its real option features. Even in a risk-neutral setting, creating real option features in an existing investment increases value by providing flexibility in the decision-making process. Since most of the papers are in the context of multinational corporations, operational flexibility in the form of switching production or sourcing locations is the most prevalent type of operational hedging strategy.

In addition to operational flexibility, geographical diversification is discussed as another operational hedging strategy in a multinational context. Geographical diversification is aligning the costs and revenues of a firm so that they are exposed to the same risks. Domestic firms selling to foreign markets can ensure that their production costs and sales revenues are exposed to the same exchange rate uncertainties by opening a production facility in these markets. As in the case of operational flexibility, firms reduce their downside exposures to exchange rate risks by eliminating the negative effect of appreciated local currency (in the form of higher production costs). However, different from operational flexibility, firms also sacrifice the gains in the upside by forgoing the positive effect of depreciated currency (in the form of lower production costs). Therefore, geographical diversification reduces the total variability of cash flows.

Chowdry and Howe (1999) consider opening a production facility in a foreign market as the operational hedging strategy of multinational firms without differentiating between geographical diversification and operational flexibility. They analyze the

conditions under which firms engage in financial and operational hedging strategies with respect to exchange rate and demand risks. They state that by having plants in several countries, multinationals can align their costs and revenues besides shifting production among these locations. They argue that the facility location decision is considered to be an operational hedging strategy only when firms are concerned with the variability of their operating profits.

Hommel (2003) considers geographical diversification and operational flexibility in the form of a real switching option as two separate operational hedging strategies. He investigates the incentives of firms to hedge currency risk with financial and operational (there, “operative”) means in a multinational context. The hedging motivation is introduced through a minimum profit constraint such that firms have incentives to hedge their payoffs to satisfy this constraint. He argues that operational flexibility is employed as a hedging device when the exchange rate and demand volatility are sufficiently large (in that case the minimum profit constraint is violated); otherwise it serves as a value driver to enhance expected profits.

These papers emphasize that because operational flexibility can be used for a purely value-enhancement motive, it is considered to be an operational hedging strategy *only* when there is a risk hedging motive for employing it. Generally speaking, operational actions are considered to be operational hedges if they are taken in order to reduce a risk measure of concern. In particular, if firms care about downside risk (e.g. having a minimum profit constraint), then operational hedges mitigate risk through a reduction in the downside exposure. If variance of the payoffs is the risk measure under consideration (e.g. having a convex tax schedule), then operational hedges mitigate risk through a reduction in variance.

In empirical research in risk management, operational hedging strategies are always studied in conjunction with financial derivatives in an exchange rate or commodity setting. Geographical diversification and operational flexibility are the operational hedging strategies implemented through different operational decisions. This field mainly investigates the substitutability or complementarity of operational and financial hedging instruments and tests whether firms use risk management activities under different risk management motives.

Fok et al. (1997) consider locating production facilities in major foreign markets to minimize foreign exchange rate exposure, and choosing a technology to minimize exposure to commodity price risk to be production-originated hedging instruments of multinational firms. Although the term “operational hedging” is not used, the former is simply geographical diversification whereas the latter is similar to a product differentiation strategy (Miller 1998), which is a type of operational flexibility.

In a multinational context, Allayannis et al. (2001) proxy the operational hedging of multinationals by the level of geographic dispersion (the location of subsidiaries across multiple countries or regions) without differentiating between geographical diversification and operational flexibility. They investigate both financial and operational exchange rate risk management strategies of firms, and demonstrate how much each strategy contributes to the overall goal of mitigating risk and improving shareholder value.

In a similar framework, Doukas and Padmanabhan (2002) consider the intangible assets of firms to be operational hedging devices with respect to political risks. The authors argue that by having high levels of intangible assets, firms can compensate the loss due to the political interruption of a host government using their other assets (for example, in other countries). Observe that high levels of intangible assets provide flexibility in terms of shifting resources among countries or businesses; this is another form of operational flexibility.

In a commodity setting, Petersen and Thiagarajan (2000) focus on gold mining firms. These firms, by adjusting their mining strategies as a function of gold price, create cost structures that positively correlate with the price of gold. Operational flexibility, created by the ability to adjust cost structures, is their operational hedging strategy, and creates a natural hedge against gold price exposure.

In summary, the finance literature defines operational hedging as mitigating firms’ risks by operational means. Operational flexibility achieved through various operational means (ability to shift production, transferring technologies, product differentiation etc.) and geographical diversification are the operational hedges of firms utilized in conjunction with financial hedges. Compared to their financial counterparts, operational hedges require higher levels of capital investment (opening a production

facility), but create longer term hedges against risk exposures including risks that are not contingent on asset prices (e.g. demand risks, political risks).

2.3 Strategy and International Business

Research in the strategy field provides a more comprehensive and complete discussion of diversification and operational flexibility from different perspectives. Diversification is defined as having different lines of business through mergers and joint ventures (Wang and Lim 2003), of which geographical diversification is one type.

Kogut (1985) analyzes diversification and operational flexibility as risk management tools of multinationals. He examines how operational flexibility and diversification change the risk profiles of firms. He argues that an operational decision (the sourcing policy in this case) can create three different types of risk profile: speculative, hedged and flexible. The speculative profile is betting on one site mainly to benefit from economies of scale in operations. By matching the exchange rate exposure on the cost side with that on the profit side, the firm can create a hedged risk profile. This approach corresponds to the geographical diversification strategy discussed in the finance literature. Finally, a flexible risk profile created through operational flexibility permits the firm to exploit uncertainties by creating real options. Operational flexibility creates both arbitrage (exploitation of differences between markets such as production switching) and leverage (enhancing strategic position such as increased bargaining power in negotiations with local governments) opportunities for multinationals.

Miller (1998) says that strategic hedges, which he defines as real options, can be used to hedge corporate downside risk. He discusses operational flexibility and diversification as strategic hedges: Similar to operational flexibility, diversification is claimed to have real option benefits. In particular, diversification into new product or geographic markets has an option value through creating growth options (Kogut 1991, Kogut and Kulatilaka 1994). Other than aligning costs and revenues, by opening a production facility in a foreign country, firms can exploit being in that market by the cost effectiveness of launching new products in the same market. Under operational flexibility, Miller lists developing in-house capacity to produce inputs when a firm has negative exposure to input prices, vertical integration of a key supplier when the firm faces the price risk of a non-commodity input, reducing the price elasticity of demand

through product differentiation, and increasing customer brand loyalty and switching costs when the firm faces price competition.

In the international business literature, Pantzalis et al. (2001) define operational hedging as the firm's operational decisions (related to marketing, production, sourcing, plant location, treasury) that are best suited to managing the exchange rate exposure on the firm's competitive position across markets. Without using the term "geographical diversification," they consider the shifting of production to offset price changes with local cost changes to be an operational hedging strategy. As another operational hedging strategy, they describe the operational flexibility of multinationals in the form of shifting production and transferring resources within their network.

Carter et al. (2003) define operational hedging strategies as a combination of production and marketing strategies across the firm's operating units developed to manage long-term exposures. Other than geographical diversification, they discuss real option type operational hedging strategies such as shifting sourcing or production, exploiting growth-options, having pricing flexibility and abandoning foreign markets. Observe that all of these strategies are again types of operational flexibility.

In summary, the strategy literature focuses on operational flexibility and diversification as risk management tools without defining them as operational hedges. Operational flexibility achieved through several operational means (developing in-house capacity, product differentiation, keeping excess capacity etc.) creates both arbitrage and leverage opportunities for multinational firms. In addition to aligning costs and revenues, real option benefits of geographical diversification in the form of growth options are discussed. The international business research, similar to the finance literature, focuses on operational flexibility and geographical diversification as long-term operational hedges of multinationals against exchange rate exposures.

2.4 Summary

The operations management literature views operational hedging strategies as real options, originating from two separate, but not conceptually different definitions. According to this view, operational hedging is investing in operational flexibility, which acts as a value driver for the firm even in the risk neutral setting. The risk mitigation connotation that the word "hedging" brings is addressed by claiming that downside risk is

reduced in the first definition, whereas such a justification is not put forward in the second. Other fields define operational hedging as operational means of reducing firms' risk exposures. Operational flexibility created through real options and geographical diversification are the main operational hedging strategies studied in these literatures. Compared with financial hedging, operational hedging requires higher levels of capital investment (opening a production facility), but creates long-term hedges against risk exposures including risks that are not contingent on asset prices (such as demand risks, political risks). In particular, operational flexibility has a value creation capability through arbitrage and leverage opportunities. Therefore, in finance, this kind of flexibility is considered to be an operational hedging strategy only when there is a risk hedging rationale for using it.

3. DISCUSSION

In this section, we evaluate and critique the existing definitions of operational hedging in operations management in the context of the broader literature on the topic. Recall that in operations management, operational hedging strategies are defined as (i) real options mitigating downside risk or (ii) counterbalancing actions that do not involve financial instruments, which we interpreted as also being real options. The next subsection discusses a limitation of these definitions.

3.1 Operational hedging strategies are not only real options.

In this section, we illustrate some operational decisions that mitigate firms' risk exposures, and should therefore be considered operational hedging strategies. However, these decisions do not have real option characteristics, and cannot be captured by existing definitions.

A basic example of non-real-option type operational hedging strategies is geographical diversification as discussed in the finance literature: Domestic firms selling to foreign markets can ensure that their production costs and sales revenues are realized in the same currency and are thus exposed to the same exchange rate uncertainty by opening a production facility in these markets. As discussed in Section 2.2, this strategy reduces the negative effect of appreciated local currency but forgoes the positive effect of depreciated local currency. Since the exchange rate exposure is mitigated by operational

means, geographical diversification in the sense of aligning costs and revenues is an operational hedging strategy, but it is not a real option: It does not provide operational flexibility.

Besides geographical diversification, there are other operational strategies that provide risk reduction or risk-sharing benefits, and that do not have real option characteristics: (i) Instead of transferring the exposure to the counterparty, firms can take actions to reduce the overall risks taken by both parties; (ii) Some operational decisions might result in implicit risk-sharing between parties without relying on contractual agreements.

For example, as stated in Meulbroek (2002b), one of the major risks for Disney Corporation is the weather risk, since bad weather significantly reduces the number of visitors to Disney theme parks. However, by locating the theme park in a warm and sunny region (such as Florida), Disney created a natural hedge against weather risks. The location decision reduced the overall exposure of both the firm and its customers (both parties) to the weather risk by reducing the likelihood of unfavorable states of nature (bad weather). Another way of reducing Disney's weather risk through operational means is locating smaller-size theme parks close to major population centers (Meulbroek 2002a). This type of theme park draws single-day visitors rather than multiple-day visitors, inducing a change in perception of weather risk among customers: For short-term visits, customers care less about bad weather risk, and are willing to bear the risk. The location decision provides implicit risk-sharing benefits since Disney shares the weather risk with its customers who internalize and bear it. In contrast to the first type of location decision, Disney creates an operational hedge by reducing the consequences of unfavorable states of nature, and not by altering the likelihood of these states.

These strategies, while they mitigate firms' risk exposures, neither have real option characteristics nor are counterbalancing actions, and are therefore not covered by the current definitions of operational hedging in the operations management literature.

3.2 Real Options are operational risk management tools, but not necessarily hedging tools.

In the previous section, we argued that real options are not the only operational means in hedging firms' risks. In this section, we argue that real options should not be

equated with operational hedging: Although real options are operational risk *management* tools, they are not necessarily used as risk *hedging* devices. The operations management literature sees real options as analogs of financial options, which are risk hedging devices, and for this reason considers them to be operational risk hedging devices. This creates an inconsistency between the way in which real options are discussed in the operations management and the other literatures.

Risk management in the broad sense is not equivalent to risk hedging (Triantis 2000, MacMinn 2002). Instead, it is the creation or preservation of firm value through managing exposures. One example for risk management without hedging is speculation with financial derivatives. In the finance literature, financial markets are assumed to be efficient and therefore there is typically no room for arbitrage. Nevertheless, when there are arbitrage opportunities, firms can choose to speculate on financial markets to create value (Moschini and Lapan 1995). In this case, firms can exploit their risk profiles and take positions that increase their exposures.

Similarly, in exercising a real investment opportunity, it can be in their best interest for firms to increase their risk exposures. In particular, real options have value-enhancement capabilities in addition to their hedging benefits: Creating real option features in an investment provides flexibility in the decision-making process. For this reason, real options are operational means of *managing risks*, but they are not necessarily used as operational hedging strategies that decrease the risk exposure. Indeed, the finance literature considers real options to be operational hedging mechanisms *only* when firms utilize them as a result of concerns about the volatility of their payoffs in the presence of market imperfections (Chowdry and Howe 1999, Hommel 2003).

In the operations management literature, real options are called operational hedging devices even in a risk-neutral setting (a setting typically used in this literature) because they increase expected profit by exploiting uncertainty. As we said above, the finance literature requires the firm to have a risk minimization motive to consider an operational action to be an operational hedge. Therefore, in the finance literature, counterbalancing capacities in a risk-neutral world and in the absence of market imperfections (as in Van Mieghem 2003) would not be considered as *hedging* devices.

3.3 Real options do not necessarily decrease the downside risk or variance of total payoff.

Operational hedges are said to reduce the downside risk of the firms (Huchzermeier and Cohen 1996). However, following the previous section's discussion, we demonstrate that real options do not necessarily decrease the downside risk (or the variance) of firms' payoffs.

The argument that real options enable firms to limit their downside risks while keeping the upside potential alive (Triantis 2000) is valid when all else is kept equal, that is, the only change in the environment is the existence of real options. This is very intuitive: Firms exercise their real options under unfavorable states of nature, and truncate their downside losses by utilizing these opportunities. However, the existence of real options might alter other operational decisions of firms. In that case, after exercising the real option and optimally resetting the levels of decision variables, the downside risk exposure or variance of this new payoff might be higher than that without the real option. Put differently, as argued in the previous section, after exercising their real options, firms may optimally adjust their operational decisions to exploit more of the underlying uncertainties.

To illustrate this, we consider the multinational firm that makes capacity and logistics decisions with or without the allocation option (Ding and Kouvelis 2001). The authors call this real option an operational hedge, referring to the first definition of operational hedging by Huchzermeier and Cohen (1996). In their model, the multinational firm producing domestically and selling only in a foreign market has to decide the production quantity and how many of those units to transfer to the market (the logistics decision). The allocation option refers to the option of delaying the logistics decision until after the demand and exchange rate uncertainties have been resolved; otherwise the quantity shipped equals the quantity produced. Assume that without the allocation option, the expected unit revenue is less than the production and logistics cost per unit. Then the firm optimally chooses not to produce at all. If it has the option to postpone the logistics decision, the firm calculates the expected value of the minimum of incremental profit (unit price minus unit transportation cost) and zero, since the firm has the option not to transfer any quantity if the incremental profit is negative. If the

expectation is larger than the unit production cost, then the firm optimally commits to a positive production quantity. Notice that without the allocation option, the operating cash flows are constant (zero), but the existence of postponement creates a random cash flow stream that may involve negative realizations. Employing expected loss (Huchzermeier and Cohen 1996, Szego 2002) as the downside risk measure, which is the expected value of negative deviations from a reference level, and setting the reference level to zero, we conclude that the existence of the allocation option increases the downside risk of the firm. Other examples demonstrating the same phenomenon can easily be developed.

In the operations management literature, operational hedging strategies are said to decrease the downside risk, and postponing the logistics decision is one of the cited operational hedging strategies (Cohen and Huchzermeier 1999). However, as we illustrated above, the downside risk of the firm does not necessarily decrease when operational hedging strategies impact other operational decisions. And the existence of additional operational decisions other than exercising real options is common in the operations management literature. We conclude that care must be taken when claiming that strategies that are classified as operational hedging reduce the downside risk: they are guaranteed to decrease the downside risk only if no other operational decisions are modified due to the existence of the real option.

Although one school of thought in the finance literature argues that the primary goal of corporate risk management programs is to eliminate the probability of costly lower-tail outcomes, i.e. the downside risk (Stulz 1996), variance is also utilized as a risk measure (Chowdry and Howe 1999). The operations management literature has recently incorporated risk aversion through mean-variance type utility functions (Chen and Federgruen 2000, Gaur and Seshadri 2001) and operational hedging has been analyzed in the mean-variance framework (Ding and Kouvelis 2001, Van Mieghem 2003). Since hedging is mitigating the risk exposure, one may expect an operational hedge to decrease this risk measure. However, as mentioned in Ding and Kouvelis (2001), when the exchange rate and demand distributions are correlated, then the allocation option may in fact increase the variance of the firm's operating profits. In this case, not only the existence of additional operational decisions, but the use of variance as the risk measure drives this result: a measure of dispersion (variance, in this case) can be adopted as a risk

measure only if the distribution is symmetric (Szego 2002). Moreover, variance is the perfect indicator of risk when comparing two normal or uniform distributions (Eeckhoudt and Gollier 1995, p.82); and is not applicable to newsvendor-based models such as in Ding and Kouvelis (2001) and Van Mieghem (2003).

4. CONCLUSION

Intense market competition and high levels of economic and technological uncertainties inherent in the business environment fuel the growth in corporate-level risk management programs. According to the finance literature, there are several sources of market imperfections that make volatility costly to firms and that can be managed through firm-level risk management activities. Financial instruments are effective in managing the exposures dependent on asset prices such as exchange rate, interest rate and commodity price. However, many firms have risks stemming from their operations that are not tradable in capital markets by means of financial contracts. For this reason, operational hedging - drawing on operational tools to hedge risks - constitutes an important component of firm-level risk management programs. Indeed, empirical research shows that firms employ operational means to manage their risk exposures (Allayannis et al. 2001, Pantzalis et al. 2001).

Operational hedging has been discussed in a variety of fields. Operations management research employs two separate, but conceptually similar, definitions of operational hedging. However, these definitions do not capture the complete range of operational hedging strategies discussed in the broader literature. According to one definition, operational hedges are referred to as real compound options of multinational firms that decrease the downside risk. The second definition states that operational hedging consists of non-financial counterbalancing actions in the processing network. As discussed in Section 2.1, both definitions refer to real options (that create operational flexibility) as the primary form of operational hedging strategies. However, there exist other operational activities mitigating firms' risks, as discussed in other academic fields, which do not carry real option characteristics. In particular, geographical diversification and operational decisions that provide risk-sharing benefits are non-real options type operational hedging strategies.

Moreover, we establish some inconsistencies in the definition of operational hedging between the operations management and the finance literatures, as well as within the operations management field. Operational flexibility, because of its real option characteristic, has a direct value-enhancing capability. Consequently, the finance literature refers to operational flexibility as a hedging tool only when firms do care about hedging their risks; otherwise it is considered to be a risk management device. However, one definition of operational hedging in the operations management literature considers counterbalancing capacities in a risk-neutral and perfect-market setting as operational hedging, which is not consistent with other fields. The other operational hedging definition considers operational hedging strategies as means of reducing downside risks. However, when there are additional operational decisions to take, the availability of real options might induce firms to increase their downside risk or variance of total payoffs after optimally re-selecting levels of these operational decisions.

In summary, while the existing definitions of operational hedging in operations management capture the fundamental principles of operational hedging, they are not complete or fully consistent with the usage in other academic fields. We believe that there is room in operations management for an operational hedging framework that incorporates and unifies findings from other fields.

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