

## Using financial derivatives to hedge against market risks in IT outsourcing projects – a quantitative decision model

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Besides the project-inherent risk of an information technology (IT) outsourcing project, related to the *management* of the project, other types of risk *driven by the markets* have not been addressed until now. Although financial derivatives are well known as a powerful tool for hedging market risk, there are no approaches to utilize this tool for risk management in IT outsourcing projects. We show a way to address two types of market risk threatening outsourcing success: insolvency of the project counterpart and a slump in prices of the counterpart's stocks. This paper therefore provides a quantitative decision model to determine how much money should be spent on hedging these risks using financial derivatives. We discover that the lower the probability of damage the higher the degree of cheap hedging that should be applied. In contrast, other means of hedging should be considered when facing a rather high probability of damage, because financial hedging gets too expensive.

**Keywords:** IT-outsourcing; market risks; hedging; decision model

### 1. Introduction

Despite winning an 'Outsourcing Excellence Award' together with Wipro in 2007 (Business Wire India, 2007), the Canadian telecommunication equipment manufacturer Nortel filed for bankruptcy only two years later in 2009 (CBC News, 2009). From 2000, the breakdown of Baan (Baker, Spiro, & Hamm, 2000) made many of their clients overthink their outsourcing strategy and change to other providers. In general, an information technology (IT) outsourcing provider and its client face several risks when agreeing on an IT outsourcing contract. Besides all the project-inherent risks that occur within an IT outsourcing project, the client could expect that it would suffer financial damage if the service provider suddenly became insolvent and wasn't able to continue the ongoing IT outsourcing project. On the other hand, the service provider might also be concerned about a possible heavy slump in the client's stock price. This would not necessarily lead to the client's insolvency, but it is possible that the resulting pressure on its management might negatively affect the IT outsourcing project and eventually lead to financial damage for the service provider. Furthermore, the case of a client filing for bankruptcy and a service provider suffering a heavy slump in prices might also be conceivable. Figure 1 exemplarily illustrates the two types of risk analyzed in this paper.

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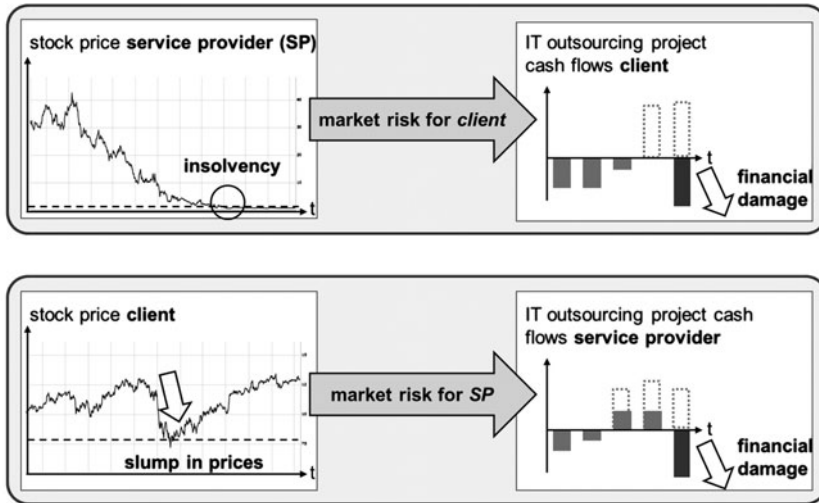


Figure 1. Market risk causes financial damage to IT outsourcing partners.

Both types of risk in IT outsourcing projects, insolvency of the project partner and a heavy slump in the project partner's stock price, are induced by the markets and can lead to enormous financial damage. As budgets for IT outsourcing projects are rising, the possible damage in case of IT outsourcing failure rises too. IT outsourcing projects, in particular, suffer from very high switching costs when trying to transfer unfinished customer tailored projects from one service provider to another. These costs have to be shouldered when being forced to cancel a failed IT outsourcing relationship due to an insolvent project partner. Feeny and Willcocks (1998) name substantial switching cost 'the single most threatening aspect of IS/IT outsourcing' (p. 15). Furthermore, a heavy slump in prices of the project partner's stocks, on the one hand, might contingently lead to increased cost pressure, resulting in budget cuts or even (sub-)project cancellations, and, on the other hand, could eventually provoke changes in management and replacement or layoffs of project staff, which in turn might induce loss of trust between the partners, ultimately resulting in financial damage. Hence, especially in IT outsourcing projects, such risks must not be neglected and adequate measures of risk management have to be explored, even if these risks are related to rather rarely occurring events in IT outsourcing. For sustainable success, companies must consider and address even long-term risks to avoid possible future financial exposure.

Financial derivatives are commonly used for hedging market risks and a proved remedy outside the Information Systems (IS) discipline. Instruments like futures or options can be bought to neutralize price risk or provide insurance (Hull, 2009, p. 11). They offer a financial payoff in case of particular events on the markets (e.g. a slump in stock price). This payoff can be used to soften the pain of financial damage that comes along with such events. Hence, the two IT outsourcing partners could consider hedging the respective risk in their project by using financial derivatives and thereby securing their project cash flows. Until now, the IS literature has provided different ways of using models from the finance discipline (e.g. real options) for *evaluating* IT projects. In this paper, we show ways of actually *using* (meaning buying) financial derivatives in order to hedge the market risk of outsourced IT projects. In analogy to an

insurance contract that covers rare but heavy damages, this hedging approach addresses exceptional events in IT outsourcing that might induce enormous financial damage. It could be argued that this approach is only interesting in times of financial and economic crisis when presumably solid companies may get under pressure. In contrast, in our paper, we use a formal-deductive and design-oriented model to illustrate that financial hedging might be a reasonable approach especially in times when there is no crisis and volatility is low, thus helping to survive the next crisis.

## 2. Research objectives

Bahli and Rivard (2003) state that IT outsourcing is believed to generate major benefits, though it can also be 'a risky endeavor' (p. 211). Complementary to the thereby existing project-inherent types of risk, i.e. related to the management of the IT outsourcing project, we want to address the types of risk that depend on changes in the economic condition of the involved outsourcing project partners and are driven first of all by the markets. In this context, the risk of insolvency of the outsourcing project partner has been rather ignored by the IS literature up to now and mainly addressed by the legal literature, e.g. Spiotto and Spiotto (2003). As possible results of a heavy slump in prices of the client's stocks, IT outsourcing projects may be put on hold or even cancelled, existing budgets may be reduced, and eventual rising loss of trust will lead to a poor outsourcing performance, because trust between the project partners is essential for outsourcing success (Fitzgerald and Willcocks, 1994, p. 94; Han, Lee, & Seo, 2008, p. 35; Koh, Ang, & Straub, 2004, p. 372; J. N. Lee, 2001. p. 332).

Focusing especially on market impacts that endanger the successful outcome of IT outsourcing projects, our research questions can therefore be posed:

- *How can the risks (a) insolvency of the project partner and (b) a heavy slump in the project partner's stock price be addressed and successfully hedged with the use of financial derivatives?*
- *Furthermore, when is a financial hedging approach applicable and when should other means of coverage be used?*

To address these questions, we look at the following dependencies: From the client's point of view, hedging should generate a payoff for the client, if the service provider becomes insolvent. This insolvency is most likely linked to the service provider's stock becoming a penny stock. The payoff should be able to cover the client's financial damage, including, for example, switching costs and lost profit. From the service provider's point of view, hedging should generate a payoff for the service provider, if there is a slump in the client's stock prices. This payoff should be able to cover the service provider's financial damage due to budget cuts, project cancellations, or loss of trust between the two partners.

The client and the service provider might therefore use financial derivatives that pay off if the counterpart's stocks drop under specified thresholds. To cover against the risk of insolvency the client could, for example, buy a derivative that pays off if the service provider's stocks drop below \$1. This will most certainly happen if the service provider files for bankruptcy. The service provider could use a derivative that pays off if the client's stock loses, for example, 30% of its original value, as such a loss might eventually induce financial damage for the service provider.

The paper proceeds as follows: Subsequent to a brief review of the related literature, we present the basic setting and assumptions of our approach. After defining the possible cash flows and their respective probabilities, we develop our objective function. We then analytically identify the optimal degree of hedging. For a deeper analysis, we give a more detailed view on how to calculate the relevant probabilities. A concluding sensitivity analysis provides meaningful, and in parts counter-intuitive, insights. Finally, we address practical implications and limitations and provide an outlook on possible future research.

### 3. Relevant literature in the context of market risks in IT outsourcing

IT outsourcing is defined as the decision on relocating IT departments' tasks to a third party vendor (Apte et al., 1997, p. 289; Loh and Venkatraman, 1992, p. 9). The main motives for outsourcing are cost reduction and the focus on core competencies (Dibbern, Goles, Hirschheim, & Jayatilaka, 2004, p. 7; Lacity & Willcocks, 1998, p. 364). Dibbern et al. (2004) and Lacity, Khan, and Willcocks (2009) provide detailed reviews of the IT outsourcing literature. Growing significance and size of IT outsourcing projects lead to an increased concern with the issue of risk mitigation (Willcocks, Lacity, & Kern, 1999, p. 286). Thus, many articles focus on the assessment and controlling of IT outsourcing risk, for example Aron, Clemons, and Reddi (2005), Aubert, Dussault, Patry, and Rivard (1999), Aundhe and Mathew (2009), Fridgen and Müller (2011), Iacovou and Nakatsu (2008), and Taylor (2006).

Very little research exists on dealing with IT outsourcing risks that are not dependent on project management quality but on the economic condition (market risks) of the involved project partners, although these market risks can have heavy negative financial impact, too. Nevertheless, the general importance of these risks (insolvency of the project partner and a heavy slump in prices of the project partner's stocks) has been addressed in IS literature. Regarding the risk of insolvency, Aubert, Patry, and Rivard (2001, p. 6) and Ngwenyama and Sullivan (2006, p. 8) point out that financial stability is an important risk factor in IT outsourcing projects. Kern, Willcocks, and Lacity (2002, p. 118) name the risk of a supplier going out of business when it comes to outsourcing provider selection. They therefore propose to select a supplier with sound financial position, stable customers and stable strategic partners as outsourcing partner. Marston, Li, Bandyopadhyay, Zhang, and Ghalsasi (2011, p. 182) name the risk of a service provider's bankruptcy as a legitimate concern when sourcing the IT into the cloud. Though not leading to insolvency, a heavy slump in prices of the counterpart's stocks might have several impacts on an IT outsourcing relationship. While budget cuts and project cancellation by the client are usually not made public, they directly induce financial damage for the service provider. A change of the client's management might furthermore negatively affect the mutual trust between the project partners. Hartman and Ashrafi (2002) empirically confirmed the importance of effective communication on IT projects. Formal outsourcing contracts are important, but trust between the partners is critical for overall outsourcing success (J. N. Lee, Huynh, and Hirschheim, 2008, p. 147; Sabherwal, 1999, p. 85). By using trust-based integrative models and survey data collected from IT outsourcing projects, the importance of trust between service receiver and provider for IT outsourcing success was verified (J. N. Lee et al., 2008; J. N. Lee and Choi, 2011). Fernandez (2003, p. 251) hints at the negative relation between trust and costs of control/safeguard strategies in IT projects. As a conclusion, loss of trust has a negative effect on IT outsourcing success as it leads to increasing costs.

Hence, an indirect link between a heavy slump in prices and financial damage due to loss of trust might be conceivable.

In IT outsourcing relationships, service level agreements are a common tool to ‘monitor the service provider’s performance so deficiencies can be adequately measured and penalized’ (Goo, Kishore, Rao, & Nam, 2009, p. 140). However, the service provider ‘can simply go bankrupt and damages may never be recovered’ (M. K. O. Lee, 1996, p. 12). The concept of source code escrow should provide access to the source code for the client in the event of the service provider’s bankruptcy. Hence, in IT outsourcing projects with a focus on software development, a client might use a source code escrow agency to reduce the financial damage in case of an insolvency of the service provider. However, there are many legal difficulties under bankruptcy law and software escrow sometimes fails its essential purpose (Pappous, 1985, p. 326).

The idea of adapting financial methods to IT project management has already been implemented in the IS literature. Gull (2011) suggests the usage of options for the valuation of discount options in software license agreements. In addition, existing real options approaches present a theoretical method for evaluating IT projects, but they are not actually purchasable financial derivatives. For example, Benaroch (2002) proposes the planning and embedding of real options in IT investments in order to control various risks. ‘Options thinking’ (p. 75) therefore is a way to acknowledge and manage uncertainty in IT projects (Fichman, Keil, & Tiwana, 2005). However, an approach for hedging financial risks in IT outsourcing projects by actually buying financial derivatives has not been provided yet. We will present such an approach as a first step in such a direction in the following section.

#### 4. A model supporting hedging decisions in IT outsourcing

In this section, we build an analytical model on how IT outsourcing partners could hedge the risk of insolvency and the risk of a heavy slump in prices by using financial derivatives. We find the optimal hedging strategy and discuss its implications.

##### 4.1. Setting and assumptions

For reasons of generality, we do not use the terms ‘client’ and ‘IT service provider’, but rather ‘hedging project partner’ (*HPP*) and ‘risky project partner’ (*RPP*). *HPP* is trying to hedge the risk caused by *RPP*. *HPP* is not necessarily always the client and *RPP* is not necessarily always the IT service provider. Instead, the assignment depends on the situation to be examined. We assume a continuous model in which  $t_0$  denotes the beginning and  $T$  the end of an IT outsourcing project between *HPP* and *RPP*.  $r \geq 0$  is defined as the continuous risk-free interest rate.

##### 4.1.1. Damage, payoff, and hedging instruments

We call the events ‘damage occurs’ *DAMAGE* and ‘damage does not occur’  $\overline{DAMAGE}$ . *DAMAGE* is caused by *RPP* and results in negative cash flows in the amount of  $\hat{D} > 0$  for *HPP*’s project.  $\overline{DAMAGE}$  has no effect on the project. Our model focuses only on the additional cash flows that are generated by *DAMAGE* and the hedging decision made by *HPP*. All other cash flows are supposed certain and are therefore omitted in our model. To decrease model complexity, we apply the following simplifying assumptions that have no major effect on the conclusions that will be drawn later on.

*Assumption 1: DAMAGE can only occur in  $t_{DAMAGE}$ , with  $t_0 < t_{DAMAGE} < T \cdot t_{DAMAGE}$  and  $\hat{D}$  are previously known. We assume all model-parameters to be constant over the considered project time.*

The limitation of the possible damage to one previously known point in time is a strong assumption and does not depict reality. However, there are financial derivatives that can be used for hedging a damage that occurs any time. Our model could be adapted accordingly but this would only increase complexity with minimal benefits for our results. For reasons of simplicity, Assumption 1 moreover eliminates the possibility that new information is gathered after the IT outsourcing project has started. This reflects the ex-ante planning of an appropriate hedging strategy, which we propose in this paper as a first step in such a direction. Reacting to new information and therefore actively managing the financial hedging portfolio might be a very complex endeavour and is beyond the scope of this paper.

The probability  $P(DAMAGE)$  in  $t_{DAMAGE}$  is defined as  $p$ , with  $0 < p < 1$ . We can exclude the boundaries 0 and 1 from the domain of  $p$ . For  $p = 1$ , HPP would not accept the project or at least factor the damage  $\hat{D}$  into the contracted price.  $p = 0$  is omitted, because there is always a chance for any company to become insolvent or for a heavy slump in prices of its stocks, even if the probability is very small. Earlier, we discussed special characteristics of an adequate financial derivative, which we refer to as ‘hedging instrument’ from now on. Assumption 2 further defines the hedging instrument.

*Assumption 2: The financial market offers a hedging instrument that can generate a payoff in the amount of  $\hat{D}$  in  $t_{PAYOFF}$ . We assume  $t_{PAYOFF} = t_{DAMAGE} = t$ . The hedging instrument is perfectly divisible and there are no transaction costs or taxes.*

Assuming the availability of the required derivatives is quite common in the finance discipline, as they can either be created through financial engineering or they will be offered on the market if a demand exists. In practice, options or credit default swaps might be suitable hedging instruments.

An option in general gives the buyer the right, but not the obligation, to buy (call option) or sell (put option) the underlying for a predetermined price to the seller of the option (Hull, 2009, p. 6). The underlying can be a stock of a particular company, an index, commodities, or currencies, for example. In particular, a cash-or-nothing put might be a fitting hedging instrument for our purpose. A cash-or-nothing put is a so-called binary option, as it provides a discontinuous payoff. At maturity, it either pays a fixed amount of cash if the underlying ends up below the specified price (strike price), or nothing if it ends up above the specified price (Hull, 2009, p. 553). The stock price of the risky company thereby represents the underlying for the binary option. We are aware that there exists no liquid market for binary options for every company. Nevertheless, there are ways of approximating binary options using more common instruments.

A credit default swap is a derivative that provides insurance explicitly in the case of a default of a particular company. Its basic functional principle is that the buyer of a credit default swap has to pay a (periodic) fee to the seller. In case of a default of the designated company, the seller has to pay a much higher compensatory payment to the buyer. In contrast to an option, here the underlying is the default of the designated company itself, which is called credit event of the reference entity (Hull, 2009, p. 518).

We do not limit our approach to these special kinds of financial derivatives. However, we require that the hedging instrument provides a binary payoff depending on the considered risky company’s stock price or solvency as an underlying to ensure that the

risk can be hedged. Hence, commodities, interest rates, or currencies don't work as an underlying for our approach.

We label the event 'hedging instrument pays off' as *PAYOFF*, the event 'hedging instrument does not pay off' as  $\overline{PAYOFF}$ . The probability  $P(PAYOFF)$  is defined as  $q$ , with  $0 < q < 1$ . Again, the boundaries 0 and 1 are excluded from the domain of  $q$ . For  $q = 1$ , the price of the hedging instrument equals the present value of its payoff, leaving no opportunity for a hedging strategy.  $q = 0$  is omitted because no one would acquire an instrument that never pays off. In many cases, it should be possible to derive the market's opinion on the probability  $q$  from the market price of the hedging instrument.

In contrast to an insurance contract, the two events *PAYOFF* and *DAMAGE* will not always occur together: it is possible that *HPP* can get a payoff from the hedging transactions without *RPP* ever having caused financial damage (e.g. when a slump in prices doesn't result in budget cuts or loss of trust). On the other hand, *HPP* could suffer financial damage but not get a payoff from the hedging instrument (e.g. the project is cancelled due to other reasons than the stock price). This leads to four possible situations as presented in Table 1.

4.1.2. Resulting cash flows, decision situation, and decision maker

To identify the optimal degree of hedging, we define the decision variable  $\lambda$ , with  $0 \leq \lambda \leq 1$ , as the percentage of  $\hat{D}$  to be hedged.  $\lambda = 1$  represents hedging the complete amount of damage and  $\lambda = 0$  not buying any coverage. For every case, different cash flows may or may not accrue. Figure 2 gives a short illustration of the possible cash flows.

In  $t_0$ , *HPP* buys the fraction  $\lambda$  of the adequate hedging instrument, which equals hedging a part of the complete possible damage. As the costs for hedging the complete possible damage might be very high, such a practice is quite common for financial hedging attempts. This is possible as we have assumed the hedging instrument to be perfectly divisible. As the hedging instrument provides insurance in case of a default, a price is charged for its acquisition. Following Black and Scholes (1973, p. 644), this price is the discounted expected value of its payoff, considering the likelihood of the event as well as the payoff that might accrue. The acquisition costs are therefore calculated as  $\lambda \cdot \hat{D} \cdot q \cdot e^{-r \cdot t}$  ( $e^{-r \cdot t}$  is the general discount factor for the cash flows occurring in  $t$ ). Similar to an insurance premium, this price has always to be paid, regardless if there will be any default. Therefore, this cash flow accrues with certainty and is not affected by the ex ante uncertain project situation in  $t$ . In  $t$ , the possible cash flows depend on the probabilities  $p$  and  $q$ . *DAMAGE* occurs with probability  $p$  and creates negative cash flows in the amount  $\hat{D}$ . As they have to be discounted to  $t_0$ , damage is

Table 1. Overview of possible combinations of events.

	hedging instrument does not pay off ( <i>PAYOFF</i> )	hedging instrument pays off ( <i>PAYOFF</i> )
damage does not occur ( $\overline{DAMAGE}$ )	'regular case' (r)	'best case' (b)
damage occurs ( <i>DAMAGE</i> )	'worst case' (w)	'hedging case' (h)

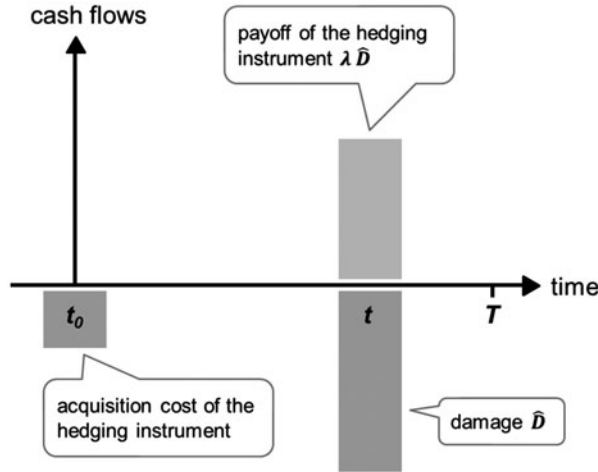


Figure 2. Overview of cash flows.

defined as  $\hat{D} \cdot e^{-r \cdot t}$ . On the other hand, *PAYOFF* occurs with probability  $q$  and pays off exactly the amount of cash which *HPP* decided to hedge by choosing  $\lambda$ . The payoff is therefore  $\lambda \cdot \hat{D} \cdot e^{-r \cdot t}$  in  $t_0$ . To keep our mathematical approach clear and to save space, we define  $D = \hat{D} \cdot e^{-r \cdot t}$ . Table 2 provides an overview of the possible cases and the corresponding cash flows that accrue for *HPP*, with ‘+’ denoting a positive cash flow and ‘-’ denoting a negative cash flow.

With four possible outcomes, we have to make a choice under uncertainty regarding  $\lambda$ . The optimal degree of hedging  $\lambda^*$  is subject to the individual preferences of the decision maker *HPP*.

*Assumption 3: The decision maker is assumed to be risk-averse and measures utility by  $U(x) = -e^{-\alpha \cdot x}$ . The decision on the optimal degree of hedging  $\lambda^*$  is made considering the certainty equivalent.*

This utility function is compatible to the Bernoulli principle (Bernoulli, 1954). The parameter  $\alpha > 0$  is its Arrow-Pratt characterization of absolute risk aversion (Arrow, 1971). The higher the value of  $\alpha$ , the more risk-averse *HPP*. A risk-averse decision maker favors the utility of a risk-free present value over a risky present value with identical expected value. Approaches similar to our model have been applied numerous times, for example in Freund (1956), Fridgen and Müller (2009), Hanink (1985), Zimmermann (2008), and Zimmermann, Katzarzik, and Kundisch (2008). Please note that in our case, the utility function  $U(x) = -e^{-\alpha \cdot x}$  measures positive and negative cash flows. The presence of risk aversion when valuating negative cash flows is

Table 2. Overview of possible cases and corresponding cash flows.

	acquisition costs of hedging instrument	damage	payoff of hedging instrument
regular case	$-\lambda \cdot D \cdot q$	$-D$	$+\lambda \cdot D$
hedging case	✓	✓	✓
best case	✓		✓
worst case	✓	✓	



controversially discussed in decision theory literature. We assume risk aversion for positive and negative cash flows, especially under the possible presence of budget restrictions for the project. We use the certainty equivalent principle as a valuation criterion for the best possible hedging implementation, as it is an established method of decision theory (Markowitz, 1959). The equation defining the certainty equivalent has the structure  $CE = U^{-1}[E(U(x))]$  and represents the amount of certain payoff which yields the same utility as a risky gamble. In our case, the risky gamble corresponds to hedging the IT outsourcing project which has four possible and therefore risky outcomes (the regular case, the hedging case, the best case and the worst case). To determine the amount of certain payoff, we need the inverse function of the utility function  $U^{-1}(x) = -\frac{1}{\alpha} \cdot \ln(-x)$ .  $x$  denotes the utility of the risky gamble, which is the expected utility of its possible outcomes (von Neumann and Morgenstern, 1947).

#### 4.2. Finding the optimal hedging strategy

To ensure that *HPP* receives the highest possible utility from the hedging decision according to the given risk aversion  $\alpha$  and utility function  $U(x)$ , we first set up and subsequently maximize the certainty equivalent for  $\lambda$ . Conducting the outsourcing project and applying a hedging strategy that covers the sought degree  $\lambda^*$  of  $\hat{D}$  is therefore the optimal strategy for *HPP*. Therefore, we consider the utility of the corresponding cash flows for each case. We define the probabilities  $p_r$ ,  $p_h$ ,  $p_b$ , and  $p_w$  as the probabilities of the regular case, the hedging case, the best case, and the worst case, respectively. With the use of Table 2 and these probabilities, we can define the certainty  $CE$  equivalent for *HPP*

$$CE = U^{-1} \left( \begin{array}{c} p_r \cdot U(-\lambda \cdot D \cdot q) + \\ p_h \cdot U(-\lambda \cdot D \cdot q - D + \lambda \cdot D) + \\ p_b \cdot U(-\lambda \cdot D \cdot q + \lambda \cdot D) + \\ p_w \cdot U(-\lambda \cdot D \cdot q - D) \end{array} \right)$$

The value of  $CE$  depends on the degree of hedging  $\lambda$  and indicates the certain amount of money that the hedging decision is worth for *HPP*. By altering  $\lambda$ , the value of  $CE$  also changes. To find the optimal degree  $\lambda$  and therefore the highest possible (or the least negative) value of  $CE$ , we differentiate  $CE$  for  $\lambda$ . We can show that the calculated candidate for optimality always represents the optimal degree of hedging  $\lambda^*$  within our model (see the appendix for Equations 1 - 3).

To determine the probabilities  $p_r$ ,  $p_h$ ,  $p_b$ , and  $p_w$ , two additional parameters are introduced that describe the interdependency between *DAMAGE* and *PAYOFF*:  $d_1$  defines the conditional probability that the hedging instrument creates a payoff if damage is present  $P(\text{PAYOFF}|\text{DAMAGE})$ , with  $q < d_1 \leq 1$ .  $d_1$  has to be greater than  $q$ . This means that *PAYOFF* is more likely if *DAMAGE* has occurred.  $d_1 = 1$  stands for certain *PAYOFF* if *DAMAGE* has occurred.  $d_2$  defines the conditional probability that damage occurs if the hedging instrument creates a payoff  $P(\text{DAMAGE}|\text{PAYOFF})$ , with  $p < d_2 \leq 1$ .  $d_2$  has to be greater than  $p$ . This means that *DAMAGE* is more likely if the financial market has triggered *PAYOFF*.  $d_2 = 1$  stands for certain *DAMAGE* when *PAYOFF* exists. These characteristics (increased probability of one event if the other event is also present) should be satisfied by the hedging instrument that *HPP* selects to

Table 3. Overview of probabilities.

$\overline{DAMAGE} \cap \overline{PAYOFF}$	$DAMAGE \cap PAYOFF$	$\overline{DAMAGE} \cap PAYOFF$	$DAMAGE \cap \overline{PAYOFF}$
$1 - q - p \cdot (1 - d_1)$	$p_h$ $p \cdot d_1$	$p_b$ $q - p \cdot d_1$	$p_w$ $p \cdot (1 - d_1)$

ensure its useful adaption. Bayes' theorem requires  $d_1 = \frac{q \cdot d_2}{p}$  (Berger, 1985, p. 129). Hence, there is a dependency between the (conditional) probabilities  $p, q, d_1,$  and  $d_2$  and only three out of four parameters have to be known. With the use of basic probability theory we can now express  $p_r, p_h, p_b,$  and  $p_w$  by  $p, q, d_1,$  and  $d_2$  (see Table 3).

Please note that  $d_2$  does not appear in any of the cases. This is due to Bayes' theorem, which allows us to replace one of the four probabilities. Using the new probabilities  $p, q,$  and  $d_1, \lambda^*$  can be written as

$$\lambda^* = -\frac{1}{\alpha \cdot D} \cdot \ln \left( \frac{q}{1 - q} \cdot \left( \frac{1 - p \cdot (1 + U(-D))}{q - p \cdot d_1 \cdot (1 + U(-D))} - 1 \right) \right)$$

We are able to find that  $\lambda^*$  is limited to the range  $0 < \lambda^* \leq 1$ . We can show  $\lambda^* > 0$  analytically and confirm  $\lambda^* \leq 1$  using a Monte-Carlo simulation. Hence, if we have a suitable hedging instrument, hedging is always superior to non-hedging ( $\lambda^* > 0$ ). The economic interpretation for the upper boundary of  $\lambda^*$  is: Hedging more than the possible damage would induce additional risk with only the expected value in return. As the expected value equals the price of hedging, this will be avoided by the risk-averse decision maker HPP. Thus, the degree of hedging will not exceed 1.

**4.3. Short example of a hedging approach**

A client (HPP) initiates a project to source its customer data to the cloud. The storage and support for the data is provided by a big service provider (RPP), which is listed at the stock exchange. To cover a possible damage in case of the default of the service provider, which is assumed to result in \$ 10 million damage and might occur in one year, the client considers financial hedging. We assume that the financial market offers a cash-or-nothing put that pays \$ 10,000, if the stock of the service provider drops below \$ 1. That means, to cover the whole possible damage, the client would need to buy 1000 contracts of the financial instrument. The financial market estimates the probability for a drop below \$ 1 to be 2%. Therefore, the financial instrument is offered for a price of \$ 196.04 (risk-free interest rate = 2%). For the case of damage when the customer data is unavailable, we assume the conditional probability to be 90% that the hedging instrument actually pays off. This means that the stocks of the service provider drop below \$ 1 at the same time. The client now has to decide how many contracts he wants to buy, from 0 to 1000 contracts for hedging from 0 to 100% of the possible damage. Without hedging, this money could be saved while being exposed to the risk of the full possible damage. Following our optimization, the resulting optimal degree of hedging in this case is  $\lambda^* = 61.8\%$ , which means that the client should buy 618 contracts of the hedging instrument. This provides a 36.3% improvement over the non-hedging alternative (buying 0 contracts). ( $p = q = 0.02, d_1 = d_2 = 0.9, \alpha = 1, \hat{D} = 10 \text{ M.}, r = 0.02, t = 1$ )

#### 4.4. Sensitivity analysis

In this section, we examine the influences of the individual probabilities on the optimal solution. Therefore we differentiate  $\lambda^*$  in subject to the probabilities and analyze the resulting effects. We have to bear in mind that Bayes' theorem will avoid arbitrarily altering all four parameters at the same time. Therefore we maintain the dependencies between  $p$ ,  $q$ ,  $d_1$ , and  $d_2$ . To study the effect of altered  $p$  and  $q$ , we assume a fixed interdependency between *DAMAGE* and *PAYOFF*. Consequently,  $d_1$  and  $d_2$  are treated as constants for the following derivatives. This can be interpreted as sticking to the chosen hedging instrument, which is acquired by the decision maker in  $t_0$ . However, with the assumption of fixed conditional probabilities, a variation of  $p$  must have an effect on  $q$  and vice versa. These effects can be deduced from Bayes' theorem. Hence, the corresponding relations are  $q = \frac{d_1}{d_2} \cdot p$  and  $p = \frac{d_2}{d_1} \cdot q$ , respectively. This means that the probability of payoff that exists at the financial market follows the rising or falling probability of damage. The exact shape of this connection is dependent on the characteristics of the hedging instrument, represented by  $d_1$  and  $d_2$ .

To determine the influence of  $p$  on  $\lambda^*$  and the influence of  $q$  on  $\lambda^*$ , we derive  $\partial\lambda^*/\partial p$  and  $\frac{\partial\lambda^*}{\partial q}$ , respectively (see the appendix for Equations 4 - 5). We find  $\frac{\partial\lambda^*}{\partial p} < 0$  and  $\frac{\partial\lambda^*}{\partial q} < 0$ , suggesting a negative relationship. In other words, the higher the probability for *DAMAGE* or *PAYOFF*, the less hedging is reasonable: The hedging instrument is too expensive compared to its risk reduction. The lower the probability for these two events, the higher the resulting optimal hedging degree: The hedging instrument is cheap enough that its price is overcompensated by the risk reduction. Hence, our hedging approach is not only valid in times of high volatility and therefore high likelihood of damage as in a financial and economic crisis, but proposes cheap hedging in times where probabilities of damage are rather low. In numbers, a rising probability of damage by the service provider in our example from 2% to 20% decreases the optimal hedging degree from 61.8% to 36.5%. On the other hand, a decreasing probability of damage by the service provider from 2% to 0.2% increases the optimal hedging degree from 61.8% to 83.3%.

To study the effect of altered  $d_1$  and  $d_2$ , we assume fixed probabilities  $p$  and  $q$  and derive  $\frac{\partial\lambda^*}{\partial d_1}$  and  $\frac{\partial\lambda^*}{\partial d_2}$ , respectively (see the appendix for Equations 6 - 7). We find  $\frac{\partial\lambda^*}{\partial d_1} > 0$  and  $\frac{\partial\lambda^*}{\partial d_2} > 0$ , suggesting a positive relationship. Thus, the greater the interdependency between the two events, or, in other words, the better fitting the chosen hedging instrument for the according risk, the higher the degree of hedging  $\lambda^*$  that should be chosen. However, the less distinctive the interdependency, the less hedging should be implemented in the outsourcing project. Again in numbers, a rising interdependency between the events of damage and payoff from 90% to 99% increases the optimal hedging degree from 61.8% to 84.1%. On the other hand, a decreasing interdependency from 90% to 50% decreases the optimal hedging degree from 61.8% to 39.7%. This mathematical result can also be explained from an economic point of view: a hedging instrument whose payoff highly echoes the damage of the underlying – in our case the IT outsourcing project – eliminates more 'risk-per-dollar' than a hedging instrument that poorly reflects the underlying.

## 5. Practical implications, limitations and outlook

This paper focuses on market risks in IT outsourcing projects that today are only addressed in a qualitative way in the outsourcing literature, but that have not been quantitatively approached up to now. Their relevance has been fortified in the latest financial and economic crisis and they should therefore be adequately treated by IT decision makers. As a first step, we propose an innovative hedging approach based on financial derivatives to address these risks with the use of a quantitative decision model. The findings are as follows:

- *Result 1:* Firms should always consider financial hedging for the addressed types of IT outsourcing risk if a fitting financial derivative is available.
- *Result 2:* The more likely it is that your project partner will cause damage, e.g. in times of a financial and economic crisis, the more expensive are hedging instruments on the financial markets and the less money should be spent for financial hedging. In contrast, you should buy more cheap financial derivatives for hedging, especially when no crisis is present and the probability of damage is very low.
- *Result 3:* The better your hedging instrument fits, meaning the more ‘risk-reduction-per-dollar’ it provides, the more hedging should be applied.

As the optimal degree of hedging determined by the model is continuous, there is no explicit line dividing a low risk from a high risk, nor one dividing a cheap hedging instrument from an expensive hedging instrument. However, the model in this paper can determine the optimal degree of hedging for any given risk and therefore gives a hint about how much you should rely on financial hedging compared to other strategies. When risk is high and hedging on the financial market is very expensive, other means of risk mitigation should be considered. As service-level agreements are useless when the contractual partner defaults, software escrow might be a minor remedy, despite its afore mentioned weaknesses. In addition, the literature suggests the concept of multi-sourcing, which might be a solution to some extent, especially in cloud computing sourcing settings, e.g. as described in König, Mette, and Müller (2013). Moreover, a financially stable project partner might consider buying its counterpart to ensure the survival of the latter, thus turning an outsourcing setting into an in-house production. Such backward integration might be reasonable if the client buys the service provider, but not vice versa. In every case, one should question the financial stability of the project partner before the start of the IT outsourcing project. If a rather high risk of default is detected, conducting the project with an entirely different project partner should be considered instead of hedging.

The restricting assumptions of this paper are necessary to maintain a comprehensible analytical approach. In the following, we address these restrictions. In Assumption 1, the limitation of the possible damage to one ex ante known point in time does not necessarily depict reality. This could be addressed in the model by introducing distributions for probability and amount of damage with respect to time. In Assumption 2, we claimed the financial derivative to pay off when damage occurs. This does not represent a problem as long as the only time of possible damage is previously known. Without Assumption 1, the financial derivative must be able to pay off at every time damage can occur. The increased flexibility of such a financial derivative leads to higher hedging costs and therefore intensifies the negative relation between probability of default and degree of hedging. Giving up the neglected transaction costs and taxes has the

same effect. A general difficulty is the determination of the required probabilities. While the probability of payoff should be easy to obtain at the financial markets and might hint on the appropriate value for the probability of damage, the conditional probabilities might be more of a problem and remain subject to the estimation of the decision maker. Nevertheless, there seems to be no reason why the effects we have discovered should fundamentally change when relaxing our assumptions.

Besides these restrictions, there is of course a lot of potential for further research. First, the client might not solely want to hedge the insolvency of the service provider but may also try to cover financial damage due to a slump in prices of the service provider (which might occur in different intensities for different triggers). Here, it might be reasonable to hedge many different triggers with many financial derivatives. Hence, the examination of the optimal hedging strategy in such cases may be a next step. Second, it would be interesting to consider that a client has several ongoing IT outsourcing projects with different IT service providers. The resulting individual hedging instruments may correlate with each other, making it necessary to examine the entire IT outsourcing project portfolio as a whole (Lacity and Willcocks, 2003, p. 116), including hedging instruments. This extension could integrate hedging into existing IT sourcing portfolio management theory as proposed by Verhoef (2005), Wehrmann, Heinrich, and Seifert (2006), and Zimmermann et al. (2008). Third, there is potential for risk adjusted pricing approaches for IT outsourcing services. A financially stable service provider could anticipate that its project partners have a cheap hedging possibility resulting from its low probability of damage. Therefore, it might be able to charge more for its services than a smaller service provider with a higher probability to create damage and thus higher hedging costs for the client.

Although in practice our model is most likely not suitable to exactly determine an optimal degree of hedging which can directly be implemented in IT outsourcing projects, a reasonable estimation is still better than completely ignoring the risk. Our model provides a theoretically sound economic approach that should encourage companies to start thinking about using financial instruments to hedge existing market risks in their IT outsourcing projects. In the future, we have to extend our view on further opportunities to adapt this idea to other types of IT project risk.

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## Appendix

To find the optimal degree  $\lambda$ , which yields the highest possible  $CE$ , we differentiate  $CE$  for  $\lambda$ :

$$\frac{\partial CE}{\partial \lambda} = -D \cdot q - \frac{1}{\alpha} \cdot \frac{\alpha \cdot D \cdot p_h \cdot U(-D + \lambda \cdot D) + \alpha \cdot D \cdot p_b \cdot U(\lambda \cdot D)}{p_r - p_h \cdot U(-D + \lambda \cdot D) - p_b \cdot U(\lambda \cdot D) - p_w \cdot U(-D)} \quad (1)$$

To fulfill the first order condition for optimality, we set the first derivative equal to 0. By solving  $\frac{\partial CE}{\partial \lambda} = 0$  for  $\lambda$  we get a candidate for optimality  $\hat{\lambda}$ :

$$\check{\lambda} = -\frac{1}{\alpha \cdot D} \cdot \ln \left( \frac{q \cdot (p_r - p_w \cdot U(-D))}{(1-q) \cdot (p_b - p_h \cdot U(-D))} \right) \quad (2)$$

To fulfill the second order condition for optimality, the second derivative  $\frac{\partial^2 CE}{\partial \lambda^2}$  has to be negative. Hence, we differentiate  $\frac{\partial CE}{\partial \lambda}$  for  $\lambda$ :

$$\frac{\partial^2 CE}{\partial \lambda^2} = \frac{(\alpha \cdot D^2 \cdot p_h \cdot U(-D + \lambda \cdot D) + \alpha \cdot D^2 \cdot p_b \cdot U(\lambda \cdot D)) \cdot (p_r - p_w \cdot U(-D))}{(p_r - p_h \cdot U(-D + \lambda \cdot D) - p_b \cdot U(\lambda \cdot D) - p_w \cdot U(-D))^2} \quad (3)$$

$\frac{\partial^2 CE}{\partial \lambda^2} < 0$  resolves to  $p_b > p_h \cdot U(-D)$ , which is always true, considering the probabilities being positive and the utility of a negative value being negative. According to our findings in the sensitivity analysis,  $0 < \check{\lambda} \leq 1$ . Therefore,  $\lambda^* = \check{\lambda}$  represents the optimal degree of hedging within our model setting.

To determine the influence of  $p$  on  $\lambda^*$ , we substitute  $q = \frac{d_1}{d_2} \cdot p$  and derive  $\frac{\partial \lambda^*}{\partial p}$ .

$$\frac{\partial \lambda^*}{\partial p} = \frac{d_2^2 \cdot (1 - d_1) \cdot (1 + U(-D))}{\alpha \cdot D \cdot (d_1 \cdot p - d_2) \cdot [d_1 \cdot p + d_2 \cdot p \cdot (1 - d_1) \cdot (1 + U(-D)) - d_2]} \quad (4)$$

In analogy, the influence of  $q$  on  $\lambda^*$  is described by the derivative  $\frac{\partial \lambda^*}{\partial q}$  with the substitution  $p = \frac{d_2}{d_1} \cdot q$ .

$$\frac{\partial \lambda^*}{\partial q} = \frac{d_2 \cdot (1 - d_1) \cdot (1 + U(-D))}{\alpha \cdot D \cdot (q - 1) \cdot [d_1 \cdot (q - 1) + d_2 \cdot q \cdot (1 - d_1) \cdot (1 + U(-D))]} \quad (5)$$

We find  $\frac{\partial \lambda^*}{\partial p} < 0$  and  $\frac{\partial \lambda^*}{\partial q} < 0$ .

To study the effect of altered  $d_1$  and  $d_2$ , we assume fixed probabilities  $p$  and  $q$  treat them as constants, when deriving  $\frac{\partial \lambda^*}{\partial d_1}$  and  $\frac{\partial \lambda^*}{\partial d_2}$ .

$$\frac{\partial \lambda^*}{\partial d_1} = \frac{-p \cdot (1 + U(-D)) \cdot [1 - p \cdot (1 + U(-D))]}{\alpha \cdot D \cdot [q - p \cdot d_1 \cdot (1 + U(-D))] \cdot [p \cdot (1 - d_1) \cdot (1 + U(-D)) + q - 1]} \quad (6)$$

$$\frac{\partial \lambda^*}{\partial d_2} = \frac{-(1 + U(-D)) \cdot [1 - p \cdot (1 + U(-D))]}{\alpha \cdot D \cdot [1 - d_2 \cdot (1 + U(-D))] \cdot [q \cdot (1 - d_2) - (d_2 \cdot q - p) \cdot U(-D) + p - 1]} \quad (7)$$

We find  $\frac{\partial \lambda^*}{\partial d_1} > 0$  and  $\frac{\partial \lambda^*}{\partial d_2} > 0$ .



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