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Risk/Cost Valuation of Fixed Price IT Outsourcing in a Portfolio Context

by

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Completed Research Paper

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Abstract

By optimizing its outsourcing strategy, a company faces the opportunity to lower the overall costs of its IT project portfolio. Without considering risk and diversification effects appropriately, companies make wrong decisions about how much of a project is reasonable to outsource. In this paper, we elaborate a model to identify a project's optimal degree of outsourcing at a fixed price, considering both, costs and risks of software development, as well as diversification effects. We also examine optimal outsourcing degrees in an IT portfolio context. To date, it is common practice to decide on the implementation of projects first and then decide on outsourcing. We provide a model that enables companies to determine an optimal outsourcing strategy which minimizes the total risk adjusted costs of an IT project portfolio by considering the portfolio decision and the selection of outsourcing degrees simultaneously. This model is then evaluated by simulation using real-world data.

Keywords: Outsourcing, IT Sourcing Portfolio Management, Portfolio Selection, Software Development Projects, Risk/Cost Valuation, Decision Model

Introduction

According to Lacity and Hirschheim (1993) firms pursue outsourcing strategies to reduce costs and mitigate risks associated with their business processes. Increased competition forces companies to deal with the cost cutting that is necessary to stay in business. Therefore, the market for outsourcing services increased significantly over time and is about to outgrow previous prospects (Aspray et al. 2006). IT service providers benefit from this development and become more specialized and competitive (Currie 1997). This provides the opportunity for companies to close more profitable outsourcing deals. Especially software development projects are affected, in consideration of the fact that today software development skills are global commodities (Dutta and Roy 2005; Lacity and Willcocks 2003; Lacity and Willcocks 2003). It is of particular importance for companies to identify a profitable software development outsourcing strategy, which encompasses not only strategic, but also economic and social perspectives (Lee et al. 2003). For the time being, in the majority of companies, a viable outsourcing strategy is either unknown or difficult to determine, because project evaluation processes are neither specified nor documented. Therefore, many companies struggle with the implementation of an integrative outsourcing strategy and still have difficulties to succeed in the implementation of IT projects. The Standish Group reports that two thirds of the IT projects fail or miss their targets (Standish Group 2006). On the contrary, Sauer et al. (2007) illustrate, when project risks are managed by a capable team, follow reasonable plans and tactics, and are of a manageable size, the outcomes are far better. To meet the desired requirement of making a project manageable, a project partitioning between a company and a service provider can be effective. Through outsourcing, projects can be managed more successfully (Slaughter and Ang 1996). Therefore, to enable a company to implement a profitable outsourcing strategy, we examine the effects of fixed price outsourcing on costs and risks of an IT project portfolio.

In today's IT departments it is common practice to decide on the implementation of individual projects first and then to decide case by case if and to what extent a project shall be outsourced. We illustrate that this causes inferior results compared to a simultaneous selection of projects and respective outsourcing degrees. For this purpose we demonstrate how a company can identify the optimal outsourcing degree of a single project as well as an optimal set of outsourcing degrees for a project portfolio. Moreover, we examine the selection of outsourcing degrees for a previously determined project portfolio and compare the results to an integrated portfolio selection and outsourcing decision. We thus provide a formal-deductive model that enables companies to determine an optimal outsourcing strategy by considering the project portfolio selection and the decision on outsourcing degrees simultaneously. The validity of our results is documented by a simulation based on data gathered in a business context. We point out that there are up to now no scientific papers addressing this special characteristic of outsourcing.

Subsequent to a brief survey of the essential literature, we describe the basic setting and assumptions of our approach. We first analyze a price negotiation between an outsourcing client and a service provider for a given degree of outsourcing. The risk-adjusted costs of a project constitute our objective function. From the objective function of a single project we deduce the one for multiple projects. We identify an optimal degree of outsourcing analytically – both, for a single project, as well as for an optimal vector of outsourcing degrees of a project portfolio. Then, we demonstrate our findings in a two projects example. We evaluate our model through simulations with real-world data. First, after describing the simulation framework, we simulate a fixed multiple projects portfolio and identify the best outsourcing solution. Second, we determine an optimal project portfolio and subsequently identify its best combination of outsourcing degrees. Third, we compare these results with a simultaneously identified best portfolio and its respective outsourcing degrees. Finally, we address practical implications, limitations and prospects of our model.

Literature Overview

IT outsourcing is defined as the decision on relocating an IT department's tasks to a third party vendor, who conducts them and charges a certain fee for the service (Apte et al. 1997; Lacity and Hirschheim 1993; Loh and Venkatraman 1992). The reasons for IT outsourcing are manifold, e.g. excess human and technological resources, focusing on core competencies, and exploitation of global strategic advantages, just to name a few. But the main motive is the cost advantage outsourcing bears, if implemented appropriately (Dibbern et al. 2004; Lacity and Willcocks 1998; Standish Group 2006). To succeed in the implementation, firms need a strategy to manage the costs and risks of outsourcing decisions (Willcocks et al. 1999). In recent years, instead of closing "outsourcing megadeals" selective outsourcing evolves, where companies decide deliberately on their outsourcing activities (Lacity et al. 1996). An integrated view of outsourcing, containing strategic, economic and social aspects, helps firms to realize the anticipated gains (Lee et al. 2003). Aron et al. (2005) coin the term “rightsourcing”, which means that a conscious risk and relationship management with multiple outsourcing vendors enables companies to reap benefits. Besides the cost and efficiency benefits, drawbacks have to be taken into account, when deciding on outsourcing. Outsourcing can entail disadvantages like unauthorized knowledge transfer, inflexibility though long term contracts, poor relationship management and accompanying poor loyalty and quality (Bryce and Useem 1998). These drawbacks must be included into the evaluation of outsourcing decisions. The costs and risks of outsourcing need to be assessed carefully. Different methods of estimating development costs are discussed in Boehm et al. (2000). The estimation of the associated risk is equally important. Many articles focus on the qualitative assessment of risk, for example Aron et al. (2005) and Willcocks et al. (1999), whereas few focus on the quantification and computation of risk, like Aubert et al. (1999).

Another research stream relevant for our contribution is the theory on transaction costs of outsourcing. Besides the risky costs of development, transaction costs occur, if a project is outsourced to an IT service provider (Aubert et al. 2004; Lammers 2004). These costs can be split into fixed and variable transaction costs. Fixed transaction costs occur as soon as certain projects or fractions of a project are outsourced, for example costs of negotiation and project initiation (Patel and Subrahmanyam 1982). Variable transaction costs are dependent on the magnitude of the fraction or project outsourced, e.g. costs of communication and control (Dibbern et al. 2006).

Investments in IT increased significantly over time, but the gains of successfully implemented IT projects are required to be managed alongside with the accompanying costs and risks, in order to reap worthwhile benefits. Therefore, firms are trying to establish a comprehensive IT portfolio management, in order to get the most advantageous rate of return (Oh et al. 2007; Weill and Aral 2005). But still, shortfalls cause the failure of numerous IT projects (Standish Group 2006). Therefore, many papers address the issue of how to govern an IT project portfolio. Quantitative approaches on IT portfolio management, e.g. Verhoef (2005), work with economic theory such as the discounted cash flow but mostly omit interdependencies between projects. Some approaches model interdependencies by using Modern Portfolio Theory (MPT) (Butler et al. 1999; Santhanam and Kyparisis 1996). Zimmermann et al. (2008) for example adapt the MPT to propose a decision model for global IT sourcing decisions. They consider the costs of site/project combinations as risky and build a portfolio optimization model.

Like most of the aforementioned articles, our model does not consider the risk of outsourcing in its entirety (e.g. qualitative vs. quantitative risk, risk of costs vs. returns). Moreover, we only consider projects which fit into strategic considerations and passed the analysis of available resources and capabilities. In this model, we focus on one specific aspect of outsourcing. We provide an economic model that delivers relevant insights supporting the design of outsourcing decision processes in today’s business.

Model

Our focus is the analysis of a situation where an outsourcing client tries to optimize the software development outsourcing strategy by minimizing the risk adjusted total costs generated by a certain project portfolio. For reasons of simplicity we focus on costs of outsourcing only, as we consider the outsourcing client’s cash inflows from a certain project to be independent from whether fractions of the projects are outsourced or not. For this paper, we model outsourcing as a fixed price and thus risk-free alternative for project development that can be used to control IT portfolio risk. Thereby, we define risk as a negative or positive deviation from an expected value (as common in finance). This corresponds to a business setting, where a contract between the outsourcing client and the vendor assures characteristics and price of the service. By outsourcing a fraction of a software development project at a fixed price, the associated risk (according to our definition) can be conveyed to the vendor. By combining internal and external development of all projects in an efficient way, the risk adjusted costs of the IT project portfolio can be lowered to a minimum. To the best of our knowledge there are no further publications regarding this effect, so this is the first contribution to this area.

In the following, each portfolio consists of a limited number of projects, each of which can be only conducted once. We consider two parties, a client as initiator of an IT project, and an IT service provider as possible contractor for partial or entire project development. For each single project, the client has to decide on the fraction that is outsourced to the IT service provider. The size of an outsourced fraction, in the following referred to as outsourcing degree, is our decision variable. We analyze if the appropriate selection of an outsourcing degree, which means an optimal combination of internal and external project development, has effects on the risk adjusted costs of a single project or a project portfolio.

We only consider development activities, which can be outsourced. Essential project phases, which have to be accomplished internally, are not taken into account. For example, we exclude tasks concerning core competencies of the client, which cannot be outsourced, as well as crucial project phases, e.g. requirements analysis. Especially the department which initiated the software request is essentially involved in the development process, at least by participating in the specification of the desired outcomes, like software characteristics concerning functionality and quality (Lacity et al. 1996).

For a better understanding, we provide a rough overview over the influencing parameters below, before we start specifying our assumptions. Since we focus on the costs of outsourcing only, we consider the outsourcing client's cash inflows on a certain project to be constant without considering the modality of development. The service provider's cash inflows are given by a certain reward he obtains for his work performed, in the following referred to as price for the externally developed fraction. In addition to the price, outsourcing a fraction of a project causes transaction costs at the client's side, which we consider risk-free. Table 1 provides a rough overview of the values relevant to the decisions of the respective party.

Table 1. Overview of the Setting

	Outsourcing Client	Service Provider
Risky costs	• Costs of the internally developed fraction of a project	• Costs of the fraction of a project developed on behalf of the client
Risk-free costs	• Price for the externally developed fraction of a project • Fixed and variable transaction costs	• --
Sum	• A project's risk-adjusted costs	• Costs of the fraction of a project developed on behalf of the client
Cash inflow	• Cash inflow of a project	• Price for externally developed fraction of a project

To distinguish the parameters of the two parties, we introduce n as a subscript representing internal, client-related variables and x as a subscript representing external, service provider-related variables. The variable $g = (1, \dots, m)$ is a subscript referencing an arbitrary but definite project, with for example $g = 7$ for project #7. As stated above, the internal costs caused by a certain project are risky. The outsourcing client wants to outsource a fraction of a project to minimize the risk adjusted costs of development. To model this situation, we make the following simplifying assumption 1:

Assumption 1

The costs of an entire project g are $C_{n,g}$ for internal development at the client's responsibility and $C_{x,g}$ for external development at the service provider's responsibility. Both are normally distributed, i.e. $C_{n,g} \sim N(\mu_{n,g}, \sigma_{n,g})$ and $C_{x,g} \sim N(\mu_{x,g}, \sigma_{x,g})$.

To decide under which conditions an outsourcing agreement is advantageous for the parties involved, we have to model the pricing of an outsourced project that, in reality, would be subject to negotiation. The outcome of this price assessment for each single project is determined by the client's and the provider's decision rules, which are specified by their respective risk adjusted costs as described in assumption 2:

Assumption 2

The risk adjusted costs are measured by both parties and follow the general structure $\Phi = \mu - \alpha\sigma^2$ with μ denoting the expected value of the costs, σ denoting its standard deviation. We define $\alpha < 0$ as the parameter of risk aversion. The outsourcing client and the service provider are risk-averse regarding costs. The risk adjusted costs of the outsourcing client shall be minimized.

The risk adjusted costs correspond to a preference function which is developed according to established methods of decision theory and integrates an expected value, its deviation, and the decision maker's risk aversion. A related model has been developed by Freund (1956). It was applied in similar contexts over the last decades, for example by Hanink (1985) and Zimmermann et al. (2008). Since normally distributed random variables and risk-averse decision makers are considered, this preference function and its corresponding utility function are compatible to the Bernoulli principle (Bernoulli 1954; Franke and Hax 2004). The parameter α, $\alpha = -2\hat{\alpha}$, conforms to $\hat{\alpha}$, the Arrow-Pratt characterization of risk aversion (Arrow 1971), but since we focus on costs not on returns, the algebraic sign changes. Here, $\alpha < 0$ indicates risk aversion. The lower the value of α, the more risk-averse is the decision maker.

According to assumption 2, the risk adjusted costs of an entire single project g follow the structure $\Phi = \mu_{n,g} - \alpha_n \sigma_{n,g}^2$ for the outsourcing client and $\Phi = \mu_{x,g} - \alpha_{x,g} \sigma_{x,g}^2$ for the service provider, respectively. For reasons of simplicity and to be able to identify an efficient outsourcing degree, we state the following assumption 3:

Assumption 3

A project is infinitely divisible between internal and external development. Every fraction of a project is perfectly correlated to every other fraction. Equal sized fractions of a project carry the same risk.

In the past, due to interdependencies in development tasks, a project could not be cut into arbitrary pieces, several cohesive parts existed. Due to recent developments in computing concepts, like service oriented architectures, software development becomes more rapid, competitive, transparent and flexible. Formerly, complex and complicated amounts of source code where produced, nowadays distinct modules of software can be developed independently from each other. Therefore, the assumption of divisibility, or at least a convergence to infinite divisibility, is justifiable. For example Zimmermann et al. (2008) make an analogous assumption.

As a consequence of assumption 3 there is a proportional relationship between the volume of a project's fraction and the costs and associated risks, respectively. This implies that the larger a considered fraction of a project, the higher the costs of development and the higher the associated standard deviation. This is obviously simplifying matters, as different phases of software projects naturally carry different risk and costs (Conrow and Shishido 1997). Nevertheless, a differentiation between project phases goes beyond the scope of this paper and is subject to further work in this area.

To identify the optimal degree of outsourcing, we define the decision variable λ_g, $0 \leqq \lambda_g \leqq 1$, as the percentage of a project's costs that refers to external development (at the service provider's responsibility). Therefore, $(1 - \lambda_g)$ is the percentage of a project's costs that refers to internal development (at the outsourcing client responsibility). The outsourcing degree $\lambda_g = 1$ stands for a project that is developed completely externally, $\lambda_g = 0$ for a project that is developed completely internally.

If a fraction of a project is outsourced to an IT service provider, transaction costs occur. These are for example costs of communication and coordination (Aubert et al. 2004). Transaction costs are either dependent on the fractions' size, or become due independently of the magnitude of the outsourced fraction. Therefore, we state the following assumption 4:

Assumption 4

When a project g is outsourced to a service provider with an outsourcing degree $\lambda_g > 0$, risk-free transaction costs $K(\lambda_g)$ occur, consisting of fixed transaction costs F_g and variable transaction costs $\lambda_g f_g$.

The fixed transaction costs are considered through a signum function[1]. The variable transaction costs are composed of the cost factor f_g, multiplied with the volume of the outsourced fraction λ_g. Therefore, the term for the transaction costs follows the structure stated below.

$$K(\lambda_g) = sgn(\lambda_g) F_g + \lambda_g f_g \tag{1}$$

Transaction costs are risk-free and become due as soon as a fraction of a project is outsourced. Besides the transaction costs, the externally developed fraction causes costs to the outsourcing client in terms of a price $P(\lambda_g)$

[1] The signum function implies, that for $\lambda_g = 0$, the term for the fixed transaction costs turns 0. Then, the entire project is developed internally, thus no transaction costs occur. For $\lambda_g > 0$, the term turns 1, i.e. if fractions of the project are outsourced. Then, the full amount of fixed transaction costs becomes due (Courant and John 1965).

that the service provider demands from the client for the service offered. The service provider and the client agree on this price, as well as on all specifications of the service, by contract.

Assumption 5

The service's characteristics and quality, as well as a certain price, are contractually assured and carry no risk for the client.

As a consequence of assumptions 1, 3 and 5, the client's expected costs of a project g with an external developed fraction λ_g, have the distribution parameters $\mu_{n,g}(1-\lambda_g)$ and $\sigma_{n,g}(1-\lambda_g)$. The service provider's expected costs of a project g have the distribution parameters $\mu_{x,g}\lambda_g$ and $\sigma_{x,g}\lambda_g$, respectively.

The negotiation of the price for the externally developed fraction is, in reality, a process of several bargaining rounds, which are difficult to picture. However, the bargaining positions of the two parties can be modeled by inserting the aforementioned distribution parameters into the valuation equations. The pricing function for an outsourced project fraction is derived in the following section.

Price Assessment

We use the individual preferences of the two parties to serve as a valuation criterion. Therefore, the price is assessed on the basis of the risk adjusted costs of the client, on the one hand, and the risk adjusted costs of the service provider, on the other. As can be seen in Table 1, the risk adjusted costs of the client are made up of the internal risk adjusted development costs, the assessed price of the external fraction, and the transaction costs. In contrast, the risk adjusted costs of the service provider are made up of the external risk adjusted development costs, only. Consequently, for each project a price assessment according to the following scheme takes place.

The price $P(\lambda_g)$ for a certain externally developed fraction of a project g ranges between an upper bound $U(\lambda_g)$, determined by the client's willingness to pay, and a lower bound $L(\lambda_g)$, determined by the service provider's minimum asking price. Between these limits, the two parties agree on an assessment outcome.

The client's willingness to pay for the external developed fraction is determined by the risk adjusted costs the development of the external fraction would cause internally. The client determines his maximum price by evaluating the risk adjusted costs which would occur if he develops the entire project by himself. Therefore, the upper bound consists of the costs and risk of the supposed additionally internally developed fraction. The covariance between the costs of the already internally developed fraction $(1-\lambda_g)$ and the supposed additionally internally developed fraction λ_g adjusts the aforementioned risk. Then, the sum of the transaction costs is subtracted. This concludes in the following formula 1:

$$\begin{aligned} U(\lambda_g) &= \mu_{n,g}\,\lambda_g - \alpha_n\left(\left(\sigma_{n,g}\lambda_g\right)^2 + 2Cov\left((1-\lambda_g)C_{n,g}\,,\lambda_g C_{n,g}\right)\right) - sgn(\lambda_g)F_g - \lambda_g f_g \\ \Leftrightarrow U(\lambda_g) &= \mu_{n,g}\lambda_g - \alpha_n\left(2\lambda_g - {\lambda_g}^2\right){\sigma_{n,g}}^2 - sgn(\lambda_g)F_g - \lambda_g f_g. \end{aligned} \tag{2}$$

For a single project, the client is willing to agree on every contract with a price below $U(\lambda_g)$, whereby a preferably low price is aspired. If the price exceeds $U(\lambda_g)$, the client would prefer to develop the entire project internally. If the price is equal to $U(\lambda_g)$, the client is indifferent between internal and external development.

The price's lower bound is determined by the minimum price the service provider must achieve to obtain at least his risk adjusted costs, given the size of the fraction he is going to develop. The specific risk adjusted costs of the service provider are the following.

$$L(\lambda_g) = \mu_{x,g}\lambda_g - \alpha_{x,g}\left(\sigma_{x,g}\lambda_g\right)^2 \tag{3}$$

For a single project, the service provider is willing to agree upon every contract with a price above $L(\lambda_g)$, whereby a preferably high price is aspired. If the price falls below $L(\lambda_g)$, the service provider is not willing to enter the commitment. If the price is equal to $L(\lambda_g)$, the service provider is indifferent whether to close the contract or not.

Since we consider risk averse decision makers, the parameter α is negative. Therefore, $U(\lambda_g)$ is positive as long as fixed transaction costs do not overweigh the advantages of outsourcing and $L(\lambda_g)$ is always positive. If an agreement interval between the two boarders exists, an outsourcing decision is favorable and a room to negotiate can be shared among the involved parties. This is the case only if $\exists\lambda_g$ with $U(\lambda_g) \geqq L(\lambda_g)$. Figure 1 shows the upper and lower bounds and the resulting agreement interval (price range).

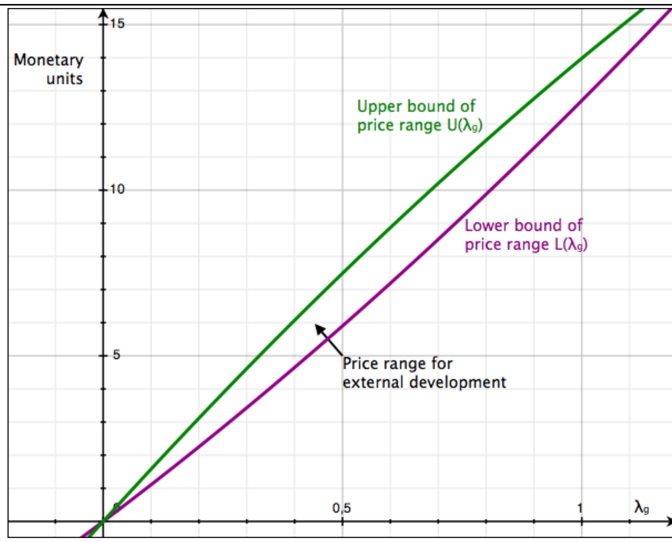

Figure 1. Price Range for External Development

Prior research offers different schemes of partitioning agreement intervals (Krapp and Wotschofsky 2004). This, however, goes beyond the scope of our paper. We present a very generic model that can be adapted to map different approaches. Therefore, we introduce the parameter γ_g. $\gamma_g \in]0;1[$ indicates a specific pricing interval share of a party. An agreement with $\gamma_g = 0$ would indicate an outcome at the lower bound, which would be favored by the client, whereas for a single project the service provider would be indifferent between closing the contract or not. An agreement with $\gamma_g = 1$ would indicate an outcome at the upper bound, which would be favored by the service provider, whereas for a single project the client would be indifferent between outsourcing and internal development of the specific project's fraction. These solutions are for the sole benefit of one party and thus not realistic. Therefore, we only consider $0 < \gamma_g < 1$.

Thus, the price $P(\lambda_g)$ of each externally developed fraction is determined by the following formula.

$$\begin{aligned} P(\lambda_g) &= \gamma_g \cdot U(\lambda_g) + (1-\gamma_g) \cdot L(\lambda_g) \\ &= \gamma_g\left(\mu_{n,g}\lambda_g - \alpha_n\left(2\lambda_g - \lambda_g{}^2\right)\sigma_{n,g}{}^2 - sgn(\lambda_g)F_g - \lambda_g f_g\right) + (1-\gamma_g)\left(\mu_{x,g}\lambda_g - \alpha_{x,g}\left(\sigma_{x,g}\lambda_g\right)^2\right) \end{aligned} \tag{4}$$

$P(\lambda_g)$ depends on the existence of an agreement interval, therefore it is only defined for $\{\lambda_g | U(\lambda_g) \geqq L(\lambda_g)\}$. For reasons of simplicity and to avoid case differentiations in the following we presume that $P(\lambda_g)$ is defined for all outsourcing degrees[2] $0 \leqq \lambda_g \leqq 1$.

Derivation of the Objective Function

The client's risk adjusted costs of development constitute the objective function which is to be minimized by choosing an optimal λ_g. They consist of the risky internal development costs and risk-free terms for transaction costs and the assessed price. The term of the transaction costs follows equation (1). The price term follows equation (4). We regard these functions and all variables besides λ_g as exogenously given, and integrate them into the objective function.

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[2] Special calculational cases might occur in boundary areas of the upper and lower bound, thus a pricing interval might not exist. Since the market for specialized and competitive service providers is flourishing, we suppose that in reality an outsourcing vendor willing to provide the service can be found for any outsourcing degree. On this condition, a positive price interval exists for all relevant cases.

Thus, the costs of single project g are represented by a normally distributed random variable with distribution parameters

$$\begin{aligned}M(\lambda_g) &= \mu_{n,g}(1-\lambda_g) + P(\lambda_g) + K(\lambda_g)\\ &= \mu_{n,g}(1-\lambda_g) + \gamma_g\left(\mu_{n,g}\lambda_g - \alpha_n\left(2\lambda_g - {\lambda_g}^2\right)\sigma_{n,g}{}^2 - sgn(\lambda_g)F_g - \lambda_{gf_g}\right)\\ &\quad +(1-\gamma_g)\left(\mu_{x,g}\lambda_g - \alpha_{x,g}\left(\sigma_{x,g}\lambda_g\right)^2\right) + sgn(\lambda_g)F_g + \lambda_g f_g\end{aligned} \tag{5}$$

as expected value, and

$$S(\lambda_g) = \sqrt{(\sigma_{n,g}(1-\lambda_g))^2} \tag{6}$$

as standard deviation. Therefore, with respect to assumption 2, a single project's risk adjusted costs are modeled according to the following structure.

$$\begin{aligned}\Phi(\lambda_g) &= M(\lambda_g) - \alpha_n\left(S(\lambda_g)\right)^2\\ &= \mu_{n,g}(1-\lambda_g) + \gamma_g\left(\mu_{n,g}\lambda_g - \alpha_n\left(2\lambda_g - {\lambda_g}^2\right)\sigma_{n,g}{}^2 - sgn(\lambda_g)F_g - \lambda_g f_g\right)\\ &\quad +(1-\gamma_g)\left(\mu_{x,g}\lambda_g - \alpha_{x,g}\left(\sigma_{x,g}\lambda_g\right)^2\right) + sgn(\lambda_g)F_g + \lambda_g f_g - \alpha_n(\sigma_{n,g}(1-\lambda_g))^2\end{aligned} \tag{7}$$

With multiple projects, the expected costs of the projects, the prices for external development, and the transaction costs are added up to the total portfolio costs. The indices i and j are referencing all projects $(1, \dots, \mathrm{m})$ considered in the portfolio. The vector $\vec{\lambda} = (\lambda_1, \dots, \lambda_m)$ contains the outsourcing degrees of all projects. Therefore, expected total portfolio costs are

$$M(\vec{\lambda}) = \sum_{i=1}^{m} M(\lambda_i) = \sum_{i=1}^{m} \mu_{n,i}(1-\lambda_i) + \sum_{i=1}^{m} P(\lambda_i) + \sum_{i=1}^{m} K(\lambda_i). \tag{8}$$

However, there are dependencies between the different projects' costs that are accounted for using correlation coefficients $\rho_{i,j}$, $0 \leqq \rho_{i,j} \leqq 1$. Please note that we only consider positively correlated projects as a negative correlation of projects is uncommon in reality (this would mean that good performance of one project systematically causes bad performance of another and vice versa). The standard deviation of the total portfolio costs including the diversification effects is

$$S(\vec{\lambda}) = \sqrt{\sum_{i=1}^{m}\sum_{j=1}^{m} \sigma_{n,i}(1-\lambda_i)\sigma_{n,j}(1-\lambda_j)\rho_{i,j}.} \tag{9}$$

To simplify matters, we do not include diversification effects in the *pricing term* – neither for the outsourcing client, nor the service provider – as this might lead to complex variations of the upper and lower bound. Due to these effects the service provider might be able to offer a lower price and the outsourcing client might be willing to pay a higher price. Thus, the price range would be broader than stated above. Besides, diversification effects in the pricing term would raise questions about the sequence of project investments. Each project would change the portfolio which serves as evaluation basis for the subsequent price negotiation. These effects would amplify the complexity of our model. Since the characteristics of the pricing term would not change severely due to the inclusion of diversification effects, and since it would have low impact on the main results of this paper, we neglect these effects that however might be subject to further research.

Instead, we take the pricing term as given and focus on the client's point of view. Therefore, the price equation for a portfolio of projects is

$$\begin{aligned}P(\vec{\lambda}) &= \sum_{i=1}^{m} P(\lambda_i)\\ &= \sum_{i=1}^{m}\left(\gamma_i\left(\mu_{n,i}\lambda_i - \alpha_n\left(2\lambda_i - {\lambda_i}^2\right)\sigma_{n,i}{}^2 - sgn(\lambda_i)F_i - \lambda_i f_i\right) + (1-\gamma_i)\left(\mu_{x,i}\lambda_i - \alpha_{x,i}\left(\sigma_{x,i}\lambda_i\right)^2\right)\right).\end{aligned} \tag{10}$$

Consequently, the risk adjusted total portfolio costs are modeled according to the following structure.

$$\begin{aligned}\Phi(\vec{\lambda}) = &\sum_{i=1}^{m} \mu_{n,i}(1-\lambda_i) \\ &+ \sum_{i=1}^{m} \left(\gamma_i\left(\mu_{n,i}\lambda_i - \alpha_n\left(2\lambda_i - {\lambda_i}^2\right){\sigma_{n,i}}^2 - sgn(\lambda_i)F_i - \lambda_i f_i\right) + (1-\gamma_i)\left(\mu_{x,i}\lambda_i - \alpha_{x,i}\left(\sigma_{x,i}\lambda_i\right)^2\right)\right) \\ &+ \sum_{i=1}^{m} sgn(\lambda_i)F_i - \lambda_i f_i - \alpha_n \sum_{i=1}^{m}\sum_{j=1}^{m} \sigma_{n,i}(1-\lambda_i)\sigma_{n,j}(1-\lambda_j)\rho_{i,j}\end{aligned} \tag{11}$$

Before exploring a situation where a company has to determine $\overrightarrow{\lambda^*} = (\lambda_1^*, \dots, \lambda_m^*)$ for multiple projects in a portfolio view, we initially focus on the determination of a single project's optimal outsourcing degree. Considering a single project's internal development costs and the price paid for an externally developed fraction, the client faces many different internal/external development compositions, i.e. different values for λ_g, to get to the desired outcome of implementing a certain project. Therefore, to provide a basis for the following extensions of our model, a first research question can be posed: *Which degree of outsourcing should a client choose for a single project to minimize the risk adjusted costs of a software development project?*

Outsourcing of a Single Project

In this section the client considers only one software development project g. As an equation containing a signum function is not continuously differentiable, we address the fixed transaction costs later on, when we simulate the results for multiple projects. For now, to be able to solve the optimization problem analytically, we set the fixed transaction costs $F_g = 0$.

The formation of the objective function to be minimized for a single project follows the scheme pictured in the previous section. In the first step we neglect that $\lambda_g \in [0,1]$ to obtain a possible minimal solution $\hat{\lambda}_g$. To fulfill the first order condition for optimality, we set the first derivative with respect to λ_g equal to 0.

$$\frac{\partial\Phi(\lambda_g)}{\partial\lambda_g} = (1-\gamma_g)\left(f_g - \mu_{n,g} + \mu_{x,g} - 2\left(\alpha_n(-1+\lambda_g)\sigma_{n,g}^2 + \alpha_{x,g}\lambda_g\sigma_{x,g}^2\right)\right) = 0 \tag{12}$$

We solve the equation for λ_g and get

$$\hat{\lambda}_g = \frac{f_g - \mu_{n,g} + \mu_{x,g} + 2\alpha_n\sigma_{n,g}^2}{2\alpha_n\sigma_{n,g}^2 + 2\alpha_{x,g}\sigma_{x,g}^2}. \tag{13}$$

To fulfill the second order condition, the second derivative with respect to λ_g has to be larger than zero.

$$\frac{\partial^2\Phi(\lambda_g)}{\partial\lambda_g^2} = 2(-1+\gamma_g)\left(\alpha_n\sigma_{n,g}^2 + \alpha_{x,g}\sigma_{x,g}^2\right) > 0 \tag{14}$$

To obtain a global minimum neglecting that $\lambda_g \in [0,1]$, the first and second order conditions have to be fulfilled. With all exogenous parameters in the previously defined domains, the second order condition (formula 14) is always true. Accounting for $\lambda_g \in [0,1]$, the parameter $\lambda_g^* = \hat{\lambda}_g$ constitutes an optimum, only if $\hat{\lambda}_g \in [0,1]$. If $\hat{\lambda}_g$ takes values below zero or larger than 1, we choose the optimal solutions $\lambda_g^* = 0$ for any $\hat{\lambda}_g < 0$, and $\lambda_g^* = 1$ for any $\hat{\lambda}_g > 1$.

In equation (13) the denominator, consisting of the combined risks of internal and external development, is always negative, since the parameter for risk aversion α is below zero. Regarding the numerator, the algebraic sign can change with a shift in costs. It shows the variable transaction costs, the spread between internal and external development costs, and the risk associated with internal development, adjusted by the parameter for risk aversion. This means that costs caused by outsourcing are compared to costs caused by internal development. If the costs of outsourcing overweigh the costs of internal development, the numerator turns positive. Hence, $\hat{\lambda}_g \leqq 0 \Rightarrow \lambda_g^* = 0$, which means that no outsourcing occurs. Else, if the costs of internal development overweigh the costs of outsourcing, the numerator turns negative. So, $\hat{\lambda}_g$ and λ_g^* turn larger than zero which means that outsourcing occurs.

The magnitude of the determined optimal outsourcing degree depends on the risk adjusted cost advantage of either development option.

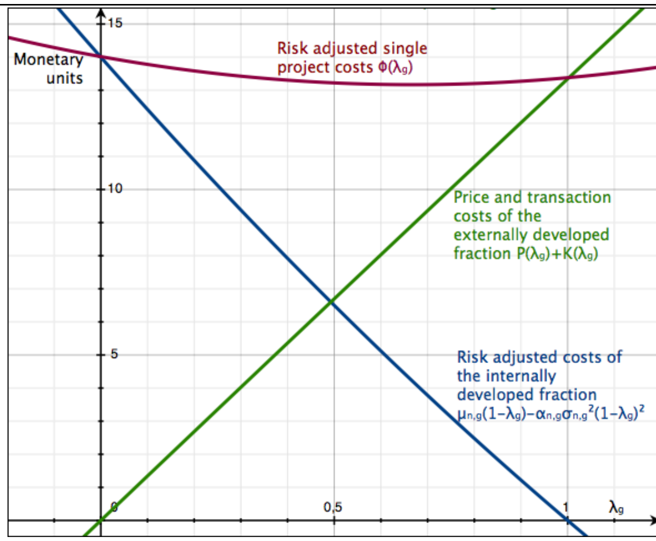

Figure 2. Optimal Outsourcing Degree of a Single Project

Figure 2 shows the decreasing risk adjusted internal development costs and the increasing price for the outsourced fraction subject to an increasing outsourcing degree. The overall risk adjusted costs of a single project are shown as aggregation of the two slopes, in the upper part of the chart. There, the optimal outsourcing degree can be identified at the curves minimum.

The optimal outsourcing degree is determined by the minimal risk adjusted costs. In the following, we expand our model to identify optimal outsourcing degrees of projects within a portfolio. Since companies conduct multiple projects simultaneously, we capture a multiple projects portfolio in the following section. Therefore, a second research question can be posed: *Which degrees of outsourcing should a client choose for a given multiple projects portfolio to minimize the risk adjusted total portfolio costs?*

Outsourcing of a Multiple Projects Portfolio

The client considers multiple software development projects in a portfolio. In the following, we want to determine the optimal outsourcing degrees of projects analytically within a portfolio view. As stated in the single project scenario, for reasons of simplicity, fixed transaction costs are not considered. Besides that, the objective function is still built according to the principles stated above.

We now face a multivariate optimization problem with a vector of decision variables $\vec{\lambda} = (\lambda_1, \dots, \lambda_m)$. Again, in the first step we neglect that $\vec{\lambda} \in [0,1]^m$ to obtain the vector $\vec{\hat{\lambda}}$ that contains a possible minimal solution. The first order condition for optimality with respect to every, arbitrary but definite λ_g with $g = (1, \dots, m)$ follows the structure

$$\begin{aligned}\frac{\partial \Phi(\vec{\lambda})}{\partial \lambda_g} &= f_g - f_g\gamma_g + (-1+\gamma_g)\mu_{n,g} + (1-\gamma_g)\mu_{x,g} \\ &+2\left(\alpha_n\sigma_{n,g}\left((-1+\lambda_g)\gamma_g\sigma_{n,g} - \sum_{j=1}^{m}(-1+\lambda_j)\sigma_{n,j}\rho_{g,j}\right) + \alpha_{x,g}(-1+\gamma_g)\lambda_g\sigma_{x,g}^2\right) = 0.\end{aligned} \tag{15}$$

Solving this equation[3] for every λ_g we get $\vec{\hat{\lambda}}$. To analyze the curvature, we have to build a Hessian matrix, consisting of all second order partial derivatives of the objective function. Differentiating twice with respect to any λ_g, the second order partial derivatives follow the structure

$$\frac{\partial^2\Phi(\vec{\lambda})}{\partial\lambda_g^2} = 2(\alpha_n(\gamma_g - \rho_{g,g})\sigma_{n,g}^2 + \alpha_{x,g}(-1+\gamma_g)\sigma_{x,g}^2. \tag{16}$$

They form the main diagonal of the Hessian matrix. The second order partial derivatives of the objective function with respect to any $\lambda_g\lambda_h$, with h as subscript referencing another arbitrary but definite project and $g \neq h$, follow the structure

$$\frac{\partial^2\Phi(\vec{\lambda})}{\partial\lambda_g\lambda_h} = -2\alpha_n\sigma_{n,g}\sigma_{n,h}\rho_{g,h}. \tag{17}$$

Apart from the main diagonal, they form the lower and upper triangular matrix of the Hessian matrix, which is built according to the following scheme.

$$H = \begin{pmatrix} \frac{\partial^2\Phi(\vec{\lambda})}{\partial\lambda_1^2} & \cdots & \frac{\partial^2\Phi(\vec{\lambda})}{\partial\lambda_1\lambda_m} \\ \vdots & \ddots & \vdots \\ \frac{\partial^2\Phi(\vec{\lambda})}{\partial\lambda_m\lambda_1} & \cdots & \frac{\partial^2\Phi(\vec{\lambda})}{\partial\lambda_m^2} \end{pmatrix} \tag{18}$$

To obtain a global minimum neglecting that $\vec{\lambda} \in [0,1]^m$, the first and second order conditions have to be fulfilled. The second order condition demands that the Hessian matrix has to be positive definite, which is always true with all exogenous parameters in the previously defined domains, since $\vec{\lambda}^T H\vec{\lambda} > 0$ for any $\vec{\lambda} \neq \circ$. Accounting for $\vec{\lambda} \in [0,1]^m$, the vector $\vec{\lambda^*} = \vec{\hat{\lambda}}$ constitutes an optimum, if $\vec{\hat{\lambda}} \in [0,1]^m$. If any element of $\vec{\hat{\lambda}}$, e.g. $\hat{\lambda}_g$, takes values below zero or larger than 1 the optimal solution is more complex to determine. On independent examination – as stated in the single project view – the solutions $\lambda_g^* = 0$, or $\lambda_g^* = 1$, respectively would be favorable for any individual project g. Nevertheless, due to the form of the objective function $\Phi(\vec{\lambda})$, every element of $\vec{\lambda}$ depends on all other elements of $\vec{\lambda}$ in an optimal portfolio. Therefore, the optimality of the objective function cannot be assured when adapting a single λ_g. As nonlinear optimization goes beyond the scope of this paper we assume for the following two projects example $\vec{\hat{\lambda}} \in [0,1]^2$. Later on, we overcome this problem and the assumption $F_g = 0$ by using simulation.

Two Projects Example

We now analyze a two projects setting for the projects g and h, respectively. Figure 3 shows the total risk adjusted costs of a two projects portfolio subject to two outsourcing degrees λ_g and λ_h.

The total risk adjusted costs minimizing outsourcing degrees, λ_g^* and λ_h^*, can be quantified as follows

$$\lambda_g^* = \frac{f_g(-1+\gamma_g) + \mu_{n,g} - \gamma_g\mu_{n,g} + (-1+\gamma_g)\mu_{x,g} + 2\alpha_n\sigma_{n,g}((\gamma_g - 1)\sigma_{n,g} + (-1+\lambda_h^*)\rho_{g,h}\sigma_{n,h})}{2(\alpha_n(\gamma_1 - 1)\sigma_{n,g}^2 + \alpha_{x,g}(-1+\gamma_g)\sigma_{x,g}^2)} \tag{19}$$

and

$$\lambda_h^* = \frac{f_h(-1+\gamma_h) + \mu_{n,h} - \gamma_h\mu_{n,h} + (-1+\gamma_h)\mu_{x,h} + 2\alpha_n\sigma_{n,h}((\gamma_h - 1)\sigma_{n,h} + (-1+\lambda_g^*)\rho_{g,h}\sigma_{n,g})}{2(\alpha_n(\gamma_h - 1)\sigma_{n,h}^2 + \alpha_{x,h}(-1+\gamma_h)\sigma_{x,h}^2)} \tag{20}$$

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[3] The equation is obviously difficult to solve for λ_g in general. See equations (19) and (20) for an example on two projects.

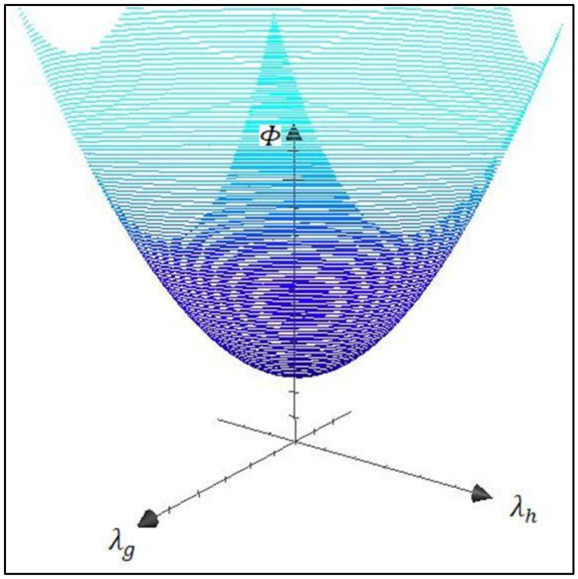

Figure 3. Optimal Outsourcing Degrees of Two Projects

As stated in the single project view, the denominators of both, λ_g^* and λ_h^*, are always negative, the extension by constants do not change any findings. The numerator contains the spread in risk-adjusted costs of outsourcing and internal development and is of either sign depending on the profitability of either option.

In the previous sections we do not take fixed transaction costs into consideration. Therefore, our results favor outsourcing even on condition that the fixed transaction costs exceed the savings due to outsourcing. Moreover, with our analytical approach we are not able to assure solutions within the domain of $\overrightarrow{\lambda^*}$ in every case. To eliminate such distortions and to provide more findings, we will use simulations in the following.

Framework for the Simulations

For the findings shown in the following sections, we generated a set of project parameters and outsourcing reference values to run the simulations, pictured in the graphs below. We suggested the following input parameters for twelve projects: expected costs, standard deviations, parameters of risk aversion, price assessment outcomes, correlation coefficients and fixed/variable transaction costs. For the estimates we adopted the proportions of the expected values and standard deviations of Zimmermann et al. (2008). The values are based on real business case data of a major IT service provider, whose identity is disguised for reasons of confidentiality. The correlation coefficients are randomly generated, equally distributed numbers between 0 and 1. For reasons of comparability we assumed equal returns of all projects. For the outsourcing degrees, we created 24,000 equally distributed reference values for each project. The probabilities of *no outsourcing* and *total outsourcing* were manually set to 5% each. Otherwise, these realistic decisions would be underrepresented in our random numbers.

For simplifying matters of expression, we use the term "efficient" for non-dominated results of our simulation, although we are aware of the fact that they could be dominated by results of a full enumeration or an analytical optimization (either one of them is very difficult to realize, therefore we proceed with a simulation).

Outsourcing of Multiple Projects within a Fixed Project Portfolio

The client considers $Q = 12$ given software development projects in a portfolio. The expected values and standard deviations of the 12-projects-portfolio with different outsourcing degrees are shown in the following diagram.

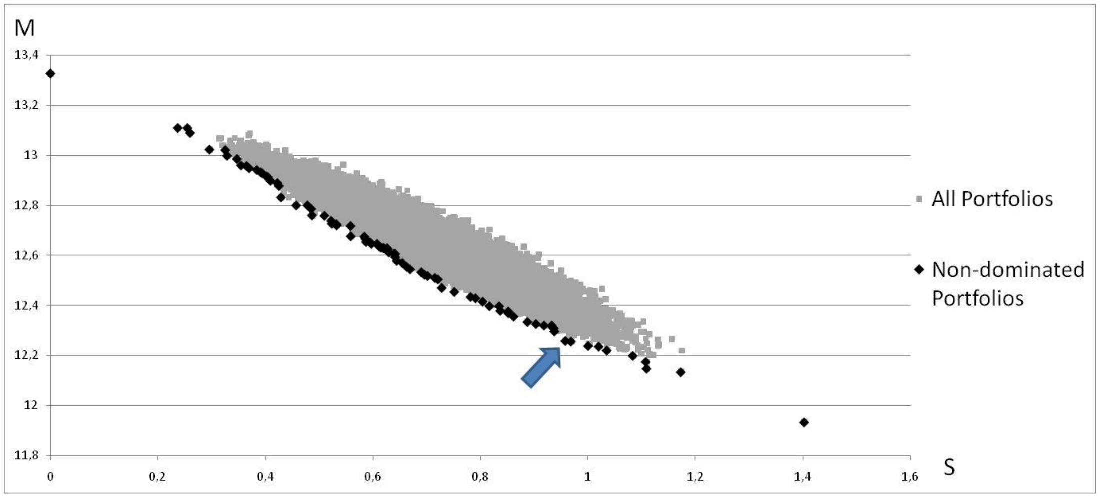

Figure 4. Fixed Project Portfolio with Random Outsourcing Degrees

Figure 4 shows a scatter plot of possible outsourcing alternatives for the fixed portfolio. A frontier of efficient portfolios is shown in dark grey. If the outsourcing client considers portfolio dependencies in the selection of the outsourcing degrees, a superior solution can be achieved. The arrow indicates the portfolio with the best allocation of outsourcing degrees identified during the simulation, which is the portfolio with the lowest risk adjusted total costs, amounting to $\Phi = 12.7169$. These solutions are only non-dominated but not necessarily optimal, because results are derived by simulation and not by optimization.

So far, we only considered a given set of projects and combined them into one portfolio and plotted it with multiple outsourcing degrees. However, a client faces multiple options to choose from and to build an efficient project portfolio. Therefore, we will picture the portfolio choice process and show its effects on the best solution. Therefore, a fourth research question can be posed: *Is it more favorable to determine efficient outsourcing degrees for a previously selected optimal portfolio than to simultaneously select both, projects and their respective outsourcing degrees?*

Outsourcing of Multiple Projects within an ex ante Determined Portfolio

To evaluate the first part of our research question, we consider a selection of an optimal project portfolio with q out of $Q = 12$ projects. We build the portfolios using complete enumeration then we pick the optimal one, which is the portfolio with the lowest risk adjusted total costs. Subsequently, for each project within the optimal portfolio 24,000 random, equally distributed outsourcing degrees are determined by simulation. Amongst all possible outsourcing combinations the best portfolio solution is identified.

In figure 5, the light grey dots show all efficient expected value- and standard deviation- combinations of portfolio selections without outsourcing. The optimal portfolio has total risk adjusted costs $\Phi = 12.7192$. All efficient portfolio combinations of partially outsourced projects are pictured in medium grey. One can see that the portfolios of partially outsourced projects dominate several efficient portfolios without outsourcing and therefore might be favored by the client. The best portfolio solution with outsourcing amounting to $\Phi = 12.6664$, is again denoted by an arrow. The portfolio with outsourcing is superior $(+0.42\%)$ to the portfolio without outsourcing.

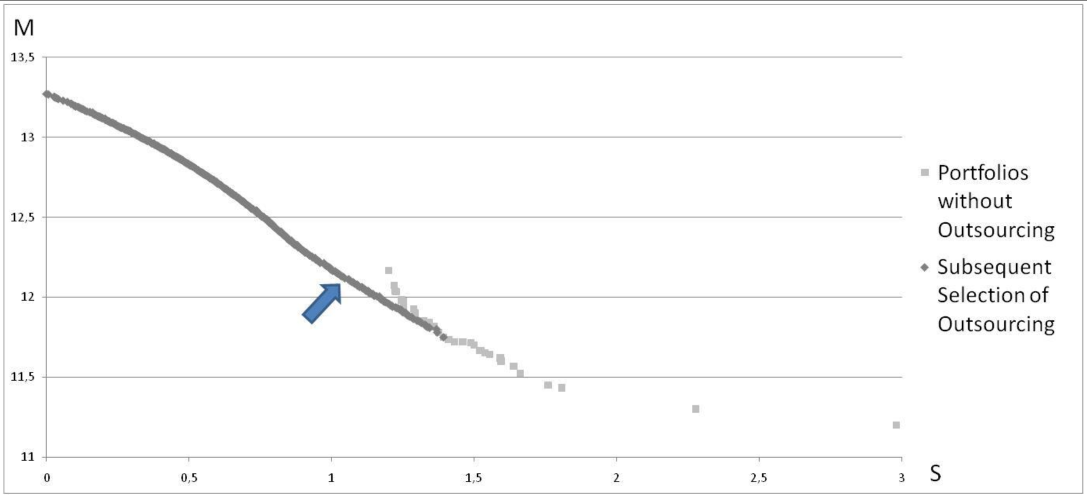

Figure 5. Subsequent Selection of Projects and Outsourcing

We examined an ex ante portfolio choice with a subsequent selection of outsourcing degrees. We now want to see if a simultaneous portfolio choice and selection of outsourcing degrees will lead to an even better solution.

Outsourcing of Multiple Projects with Simultaneous Portfolio Selection

In contrast to established business processes where outsourcing decisions are made after the decision on the composition of the project portfolio, we now choose q out of $Q = 12$ projects with their q outsourcing degrees simultaneously.

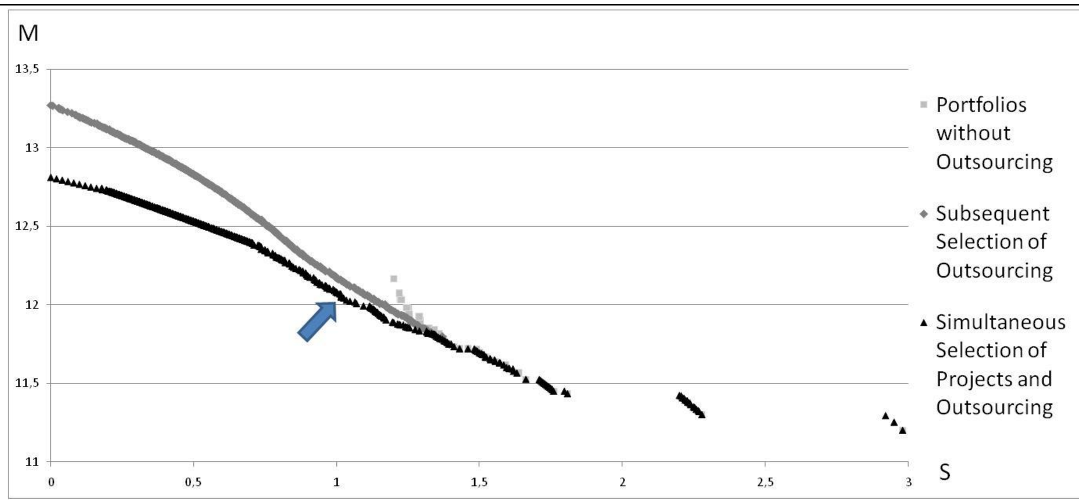

Figure 6. Simultaneous Selection of Projects and Outsourcing

Figure 6 shows a portfolio choice of q out of Q projects and **subsequent** selection of q individual outsourcing degrees for the predetermined portfolio projects as established in the previous paragraph. Furthermore it shows the **simultaneous** selection of q out of Q projects and q associated outsourcing degrees of all possible projects. This leads to portfolio compositions from which the best possible portfolio with $\Phi = 12.5638$ can be determined (indicated by an arrow). The simultaneous selection of projects and outsourcing degrees gets to a superior solution (+ 0.82%) compared to the subsequent selection, where only the outsourcing degrees of the predetermined portfolio are part of the simulation. Compared to the portfolio without outsourcing, the simultaneous selection of projects and outsourcing degrees is superior, too (+ 1.22%). Although the improvement might seem small at first sight, the benefit companies might realize should not be underestimated. Above, we compare our finally best portfolio to an already optimized portfolio without outsourcing, but to date, companies rarely use effective portfolio optimization to decide on outsourcing their IT projects. The reference values for comparison would therefore be lower in reality and the potential gains are higher. Furthermore, a major company with a corresponding IT budget might realize substantial absolute savings.

Practical Implications, Limitations and Conclusion

Today, companies increasingly realize the relevance of IT portfolio management in general as well as in the context of IT outsourcing. Thereby, they extend their focus from a pure cash-flow oriented view to a more generic one and integrate risk and dependencies into their decisions. Nevertheless, these approaches are often pragmatic and methodically weak. The vision of a value adding quantitative IT portfolio management requires methodically rigor models that deliver initial reasonable results, although they might not be suitable to be applied in practice without adjustments.

Although it bears great cost reduction potential, still little research exists in the field of fixed price outsourcing and its effects on an IT project portfolio. This paper provides a quantitative model to help companies to improve their IT outsourcing strategies. Including interdependencies between projects as well as transaction costs, we find that outsourcing an appropriate fraction of an IT project can enable a company to minimize the risk adjusted costs of a project, as well as of a project portfolio. Moreover, we discover that the simultaneous selection of outsourcing degrees and best project portfolio may lead to even lower risk adjusted total costs than the subsequent determination of the best project portfolio and outsourcing degrees.

This is of special importance as today's IT decision processes mostly feature subsequent decisions only. Companies usually decide on projects first and then evaluate possible outsourcing settings. The restricting assumptions of this paper are necessary to show analytically that this bears optimization potential. Relaxing these restrictions would make an analytical solution impossible. But still, there is no obvious reason, why these effects should not occur. A business oriented model which is directly applicable but still methodically rigor will be the objective of further research in this area. Therefore, every limitation of this paper has to be addressed separately and analyzed profoundly.

First, the exclusion of risk for a fixed price outsourced fraction might not necessarily picture reality, because for example default risks remain. In terms of this paper, these additional risks could be pictured by introducing price and transaction costs as random variables. This leads to a gain in complexity because all correlations between in- and outsourced fractions would have to be considered. This major extension of the model is our current work-in-progress. It will also include the analysis of contract types, other than fixed price outsourcing. Furthermore, we currently neglect varying returns of projects and assume them to be constant regardless of the degree of outsourcing. The implementation of projects by a specialized service provider might however have positive and negative impacts on the return, e.g. through influences outlined in agency theory. This would provide a more eclectic picture of reality.

Also, we assume infinite divisibility of projects to be able to build continuous functions and their derivatives in order to derive our results analytically. However, one has to admit that dividing arbitrary parts of projects might be technically impossible or irrational concerning economical aspects. In contrast, discrete partitioning might lead to inferior absolute outcomes. Nevertheless, the model can be used to heuristically approximate discrete results as a basis for an in-depth analysis. Additionally, the linear relationship of the fraction's size to costs and risk, requested in assumption 3, might lead to a loss in generality, since different parts of a project might entail distinct values of costs and risks. Separate observation of different project parts with different risk/cost structures might be a practical addition. Moreover, we include risk diversification effects in the objective function, but neglect them in the price assessment – for both, the outsourcing client and the service provider. The effects on the price range might as well be subject to further model extensions. Finally, our model pictures ex ante decisions only. The development of an integrated model considering the existing project portfolio as well as the decision on additional projects might be of great significance to practitioners as well as to researchers.

Although the model pictures reality in a constrained way, it provides a basis for firms to plan and improve their outsourcing strategies. Thereby, it is not only of high relevance to business practice, but also provides a theoretically sound economical approach.

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