Does collaboration pay? An investigation for the domain of distributed investment decisions

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1 Introduction

One of the most important tasks of corporate financial management is to assure the efficiency of investment decisions [16, 5]. In corporate practice, it can be observed that departments are often endowed with decision making authority regarding their investments. This is due to rapidly changing markets, products, and technologies, and decentral managers that are usually better informed with respect to these volatile economic circumstances [17].

Thus, on the one hand, decentralizing decision making brings along the opportunity to evaluate investment opportunities on a more sound basis. On the other hand, it evokes the need of coordination of the distributed investment decisions. What adds complexity on top is that the departments’ interests are often divergent which is why uncoordinated distributed decision making usually results in not achieving the corporate objective (e.g. shareholder value maximization) [18, 3, 1, 10]. Furthermore, corporate investment budgets are usually limited and investment opportunities often compete for this limited amount of financial resources [4]. Hence, it will only be possible to fund a subset of profitable investment opportunities. In order to assure the efficiency of distributed investment decision making (in terms of value maximization), well developed ‘decision making rules and procedures’ turn out to be essential. Such rules and procedures are usually embodied in coordina-
tion mechanisms which align the decentral decisions to the overall corporate objective [6, 4, 12, 13].

In our model, we utilize hurdle rates for coordination purposes. Hurdle rates are referred to as the required rate of return of an investment opportunity [5], i.e., hurdle rates are usually specified as departmental capital charges for opportunity costs. The concept of hurdle rates seems to be related to the concept of internal transfer pricing such as that hurdle rates can be regarded as the particular price which a department gets charged for the invested (or lend) amount of money. However, the standard textbook case suggests to fix hurdle rates equal to the cost of capital. This might be sufficient for the case of unlimited financial resources, but does not provide a solution for the case of multiple investment opportunities which compete for the same pot of funding. Baldenius et al. [4] take account of this circumstance and introduce the concept of the Competitive Hurdle Rate (CHR) mechanism. The CHR mechanism is a capital budgeting mechanism for coordinating distributed investment decisions which considers investment opportunities that are mutually exclusive due to scarce financial resources.

Based on divisional reports about the projects’ characteristics the CHR derives cost charges, which departments get charged in every subsequent time period in the case that they decide to operate an investment opportunity. These cost charges comprise depreciation and capital charges, whereby the capital charges are based on hurdle rates which are competitively (and similarly to a second price auction) computed on the basis of all divisional reports. Baldenius et al. [4] derive the CHR mechanism from an agency model and show that – under the specific premises – it is strongly incentive compatible. Such agency models usually assume fully rational, perfectly homogenous, and non interacting agents. Axtell [2] refers to these core assumptions as the ‘neoclassical sweetspot’. In most cases, these assumptions are made in order to assure analytical tractability [9, 8]. Hendry [7] reasons another feature which is usually incorporated into agency models, i.e., the agents’ full competence in carrying out tasks. However, given this large set of assumptions, it is plausible to assume that the agency models’ outcomes are sensitive to changes in their basic frameworks. Leitner and Behrens [12, 14] take account of the very strict ‘neoclassical assumptions’, and assume away full rationality, perfect homogeneity (regarding departments as well as regarding investment opportunities), and the department managers’ perfect competence in forecasting, which are incorporated in the CHR model [4]. By doing so, they investigate the robustness and applicability of the CHR mechanism to real world situations outside the ‘neoclassical sweetspot’. However, Leitner and Behrens [12, 14] hold up the assumption that projects are carried out by exactly one organizational unit and simply assume away spillover effects. In this paper, we soften intraorganizational boundaries and allow cooperation among departments. In particular, we adapt the CHR mechanism proposed by Baldenius et al. [4] to situations in which projects, that are carried out jointly by organizational departments, compete for scarce financial resources,
which is a novelty. Moreover, we investigate the robustness of our adapted mechanism to situations that are closer to real world situations. As suggested by Leitner and Behrens [12, 14], we consider limited rationality, heterogeneity with respect to investment opportunities and departments, and a certain level of incompetence in forecasting measures associated with investment opportunities. By comparison to the case of efficiently made investment decisions (in terms of value maximization), we narrowly characterize efficiency losses due to distributed investment decisions. Moreover, we conduct a comprehensive sensitivity analysis which allows for insights into the dynamics of coordinating decentralized and autonomous investment decisions. Since hurdle rate based coordination mechanisms as well as transfer price based coordination mechanisms seem to be frequently utilized in corporate practice [4], a further investigation of the robustness of such mechanisms appears highly relevant, also from the practitioners’ point of view. Our work complements previous research on hurdle rates in the context of corporate investment decisions,[3, 4] as well as work on the robustness of such coordination mechanisms to situations that are closer to real world situations [12, 14].

2 Simulation Model

We model organizations to consist of departments \( i (i = 4, ..., m) \) and a coordinating unit. At \( t = 0 \) departments are in charge of proposing investment projects, \( j (j = 2, ..., n) \) to the coordinating unit. Each investment project is carried out by \( z = i/j \geq 2 \) departments, whereby each department autonomously decides whether or not to carry out the project. The function \( f(i,j) \) represents whether \( f(i,j) = 1 \) or not \( f(i,j) = 0 \) department \( i \) is involved in project \( j \). Financial resources are scarce which is why at most one project can be funded. The organization aims at maximizing its shareholder value (SHV), while departments aim at maximizing their individual utilities.

The following measures are associated with investment projects: (i) an initial cash outlay, \( \kappa_j \), necessary to launch the investment project; (ii) an intertemporal distribution of cash flows, \( x_{ij} = [x_{ij1} \ x_{ij2} \ ... \ x_{ijT}] \); (iii) an efficiency parameter in operating the jointly proposed project per department, \( \rho_i \), scaling the cash flows such that the present value \( PV_{ij} \) is given by:

\[
PV(x_{ij}, \rho_i, r) := x_{ij} \circ r(r) \cdot \rho_i,
\]

where \( r(r) = [(1 + r)^{-1} \ ... \ (1 + r)^{-T}] \) denotes the vector of discount factors. Consequently, project \( j \)'s net present value (NPV) results in \( \Lambda_j(r, p_j) := \sum_{\forall i : f(i,j)=1} PV_{ij}(x_{ij}, \rho_i, r) - \kappa_j \), where \( p_j = [\rho_{i1} \ ... \ \rho_{iz}] \).}

\footnote{As each department is involved in exactly one investment project, we can suppress the notion of \( j \).}
represents the efficiency parameters of all departments which are involved in project $j$, and $r$ denotes an interest rate.

For each investment opportunity the coordinating unit calculates hurdle rates $r_1^*, ..., r_j^*, ..., r_n^*$ according to the procedure introduced in [11] and [14]. Whenever departments decide to put their proposed projects into action, they will be charged the hurdle rate for the initial cash outlay. To do so, for each investment project $j$ we compute the highest NPV of all projects other than $j$, i.e., $\Lambda_j^* = \max \{ \Lambda_1(r_c, p_1), ..., \Lambda_{j-1}(r_c, p_{j-1}), \Lambda_{j+1}(r_c, p_{j+1}), ..., \Lambda_n(r_c, p_n) \}$, and a vector of reference efficiency parameters $\rho_j^* := \Lambda_j^* \cdot p_j / \Lambda_j(r_c, p_j)$, where $r_c$ denotes the corporation’s cost of capital. The reference efficiency parameter, $\rho_j^*$, is the efficiency level at which, ceteris paribus, project $j$ is at least as profitable as $\Lambda_j^*$ (in terms of NPV). Project $j$’s hurdle rate results in the internal rate of return at the reference efficiency level, i.e., $\Lambda_j(r^* j, p_j) = 0$.

As each department autonomously decides whether or not to carry out an investment project, we need to derive an incentive compatible mode of allocating the initial cash outlay, $\kappa_j$, to the departments. We compute department $i$’s share on $\kappa_j$ according to

$$\lambda_{ij} = \frac{PV(x_{ij}, \rho_j^*, r_j^*)}{\sum_{k: f(k,j)=1} PV(x_{kj}, \rho_k^*, r_j^*)} \quad (2)$$

Next, the coordinating unit announces the hurdle rates and the shares of the initial cash outlay to the departments. On the basis of this information, each department decides whether ($I_{ij} = 1$) or not ($I_{ij} = 0$) to put the proposed project into action

$$I_{ij} = \begin{cases} 1, & \text{if } PV_{ij}(x_{ij}, \rho_i, r_i^*) - \lambda_{ij} \cdot \kappa_j > 0, \\ 0, & \text{otherwise}. \end{cases} \quad (3)$$

Given the mode of computing hurdle rates and capital shares presented above, project realization is only attractive for the investment project yielding the highest NPV. Whenever projects are realized, departments are charged according to the relative benefit depreciation schedule [15] using the hurdle rate as discount factor, and rewarded a function of residual income, $f(v_{it})$.

Representing the sequence of future compensation components by $v_i = [f(v_{i1}) ... f(v_{iT})]$, we can denote department $i$’s utility function by $U_i(r_c \circ v_i)$. Fulfilling the claim of SHV maximization, we denote the corpo-

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2 This is the core of the coordination mechanism: the capital charge rate is located below the project’s internal rate of return only for the winning project. For all other projects, the hurdle rate is higher than the projects’ internal rates of return, which - upon realization - would result in negative NPVs [4, 11, 14].

3 In every $t$, residual income results in $v_{ijt} = x_{ijt} \cdot \rho_i - \lambda_{ij} \cdot \kappa_j \cdot \frac{\rho_j^*}{r(r_j^*) \circ \kappa_i}$. This performance measure reduces to $v_{ijt} = \kappa_j \cdot (\rho_i - \rho_j^*)$ and, thus, fulfills strong incentive compatibility (cf. also [4]).
ration’s utility function by $U_c(A_j(r_c, P_j)) = r(r_c) \circ v_j$. Following the decision making rule presented in Eq. 3 both utility functions are maximized.

### 3 Simulation Setup

We model department $i$’s cash flow time series $x_{ij}$ from operating project $j$ by following a geometric brownian motion (GBM). In particular, we model two correlated cash flow paths (using a zero drift bivariate GBM), whereby one path corresponds to those actually put into effect, and the second path is the department’s forecast of cash flows. A process follows a zero drift bivariate path corresponds to those actually put into effect, and the second path is the correlated cash flow paths (using a zero drift bivariate GBM), whereby one

$$
dx^{(k)}_i = \sigma^{(k)} dB_t^{(k)}$$

where $\sigma$ is the diffusion rate, $B_t$ is a Wiener process, and $k = \{R, E\}$ denotes ‘real’ and ‘estimated’ values of cash flows. The Wiener processes are correlated such as that $E[B_t^{(R)} dB_t^{(E)}] = p_{R,E} dt$ and $p_{R,R} = p_{E,E} = 1$. We use a discrete time approximation of the above process and (arbitrarily) set a constant $\sigma^{(R)}_{ij}$ for all $i$ and $j$. Furthermore, $x_{ijt}$ is normalized to one at $t = 0$. The diffusion rates of the real and estimated cash flow paths are linked according to

$$
\rho^{(R)}_{ij} \sim U(\rho^{(R)}_0, \bar{\rho}^{(R)}), \quad \text{however, department } i \text{ faces uncertainty concerning its efficiency according to } \rho^{(E)}_{ij} = \min\left[ \rho^{(R)}_{ij} \cdot \exp(y_{ij} \cdot \frac{1-p_{R,E}}{p_{R,E}} - \sigma^2 y^2 / 2) \right] .
$$

$y$ denotes a normal random variable with $y \sim N(0, \sigma_y^2)$. The PV of each cash flow time series (real and estimated) - given the corporation’s cost of capital $r_c$ - is thus $PV_{ij}^{(R)}(x_{ij}^{(k)}, \rho^{(k)}_{ij}, r_c)$. Each project’s NPV is defined as $A_j^{(k)} = \sum PV_{ij}^{(k)}(x_{ij}^{(k)}, \rho^{(k)}_{ij}, r_c) - \kappa_j^{(k)}$, and $\kappa_j^{(R)} \sim U(\sum PV_{ij}^{(R)} - \min(PV_{ij}^{(R)}), \sum PV_{ij}^{(R)})$. The latter definition of $\kappa_j^{(R)}$ guarantees non-negative NPV projects only, and requires that every department $i$ participates in project $j$. The estimated outlay $\kappa_j^{(E)}$ of project $j$ is given by $\kappa_j^{(E)} = \kappa_j^{(R)} \cdot \exp(y_j \cdot \frac{1-p_{R,E}}{p_{R,E}} - \sigma^2 y^2 / 2)$.

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4 Using Matlab®’s function ‘portsim.m’.
4 Results

This section presents results from a large variety of parameter sets. All relevant parameters, either fixed or subject to variation in our simulation runs are presented in Tab. 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_{ij}$</td>
<td>diffusion parameter of the cash flow process</td>
<td>fixed, $\sqrt{1}$</td>
</tr>
<tr>
<td>$p_{R,E}$</td>
<td>correlation of real and estimated cash variable, ${.2, .4, .6, .8}$, equal for all departments</td>
<td>variable, ${.2, .4, .6, .8}$</td>
</tr>
<tr>
<td>$T$</td>
<td>number of periods of the project</td>
<td>fixed, 5</td>
</tr>
<tr>
<td>$\rho_{ij}^{(R)}$</td>
<td>efficiency parameter of department $i$ operating project $j$</td>
<td>random, $\rho_{ij}^{(R)} \sim U(1, 9)$</td>
</tr>
<tr>
<td>$\sigma_y^2$</td>
<td>variance of the error in efficiency and outlay</td>
<td>fixed, .1</td>
</tr>
<tr>
<td>$r_c$</td>
<td>corporate cost of capital</td>
<td>fixed, .1</td>
</tr>
<tr>
<td>$\kappa_j^{(R)}$</td>
<td>initial outlay of project $j$</td>
<td>random, uniform in the interval of positive NPV projects</td>
</tr>
<tr>
<td>$n$</td>
<td>number of projects</td>
<td>variable, ${2, 3, 4, 5, 6, 7, 8}$</td>
</tr>
<tr>
<td>$z$</td>
<td>number of departments operating one shared project</td>
<td>variable, ${2, 3, 4, 5, 6, 7, 8}$</td>
</tr>
<tr>
<td>$s$</td>
<td>number of simulation runs</td>
<td>fixed, 50,000</td>
</tr>
</tbody>
</table>

Table 1 Parameters in the simulation setup

4.1 Erroneous forecasts

We start by analyzing the effects of different corporate structures, i.e. the effect of different numbers of projects and departments operating these projects, respectively. Fig. 1 reports results from 50,000 simulation runs concerning the ratio of erroneously chosen projects (loss ratio, LR). Light (dark) areas in each subplot indicate high (low) LR, subplots refer to values of $p_{R,E}$ of $\{.2, .4, .6, .8\}$ respectively. The abscissa (ordinate) shows varying numbers of departments (projects).

It turns out that LR is increasing in the number of departments as well as in the number of projects. In other words, ‘large companies’ (either in terms of a large number of projects and/or a large number of departments) face a higher probability of choosing the wrong project due to inaccurate forecasts of cash flows efficiencies, as well as erroneous estimates of the project outlay. This is particularly true for setups with a relatively low forecasting ability (i.e., $p_{R,E} = .2$). Unsurprisingly, increasing forecasting abilities generally reduce LR. When looking at the NPV loss (NL) – which is the loss suffered from erroneously not picking the best investment project – we find that NL increases with the number of projects, but decreases as the number of departments increases (cf. Fig. 2). Further, the decreasing pattern shifts,
if departments possess higher abilities in correctly forecasting cash flows, efficiency and outlay. E.g., if \( p_{R,E} = .8 \), the NL is basically low, yet it is increasing with the number of departments. For the case of compensation losses (CL) (cf. Fig. 3) – defined as rewards\(^5\) wrongfully paid to departments operating an adverse project due to errors in forecasts – we find that the highest errors can be observed for low forecasting abilities, i.e., for \( p_{R,E} = .2 \) the maximum is at 0.35 while for \( p_{R,E} \) the errors upper boundary is 0.07. For low forecasting abilities (\( p_{R,E} = .2 \)), high CL are located in areas where the number of departments is low but the number of investment alternatives is relatively high. With increasing forecasting abilities this pattern shifts so that for the case \( p_{R,E} = .8 \) the relatively highest CL can be observed for a larger number of departments and a lower number of investment alternatives.

\[ \text{Fig. 1 LR for different combinations of } n, z \text{ and } p_{R,E}. \]

### 4.2 The impact of error sources on the mechanisms’ efficiency

This section outlines effects of a reduced number of erroneous departmental estimates. Recall that in the basic setup cash flows \( x \), outlays \( \kappa \) and the departments’ efficiency parameter \( \rho \) are subject to misestimation. We provide results if uncertainty for one or two out of these three error sources is dropped. In other words, either one or two values from the set \( \{x, \kappa, \rho\} \) is known at the very beginning of the project. We use the same parameter sets as before and conduct an analysis concerning LR, NL and CL, respectively.

\(^5\) Based on the performance measure \( v_{it} \), see Sec. 2
Fig. 2 NL for different combinations of \(n, z\) and \(p_{R,E}\).

Fig. 3 CL for different combinations of \(n, z\) and \(p_{R,E}\).

For the sake of simplicity, we report all results graphically (captions of subplots refer to known parameters respectively) in terms of changes in error measures as compared to the standard setup where \([x, \kappa, \rho]\) are subject to all errors at the same time (i.e. Figs. 1 and 2). We further only report results on good and bad forecasting abilities (\(p = \{.2, .8\}\)).
Figs. 4 and 5 depict the reduction of NL for different combinations of the number of departments and projects dependent on which parameter(s) can be perfectly forecasted by departments (cf. also Tab. 2). Obviously, for low forecasting abilities ($p = .2$), NL may be particularly lowered if the number of departments operating one joint project is low. This result applies to all versions of known parameters in the estimation process. However, when examining Fig. 5, it turns out that for high forecasting abilities perfect knowledge of one or two (out of three) values estimated by the departments yields diverse effects in terms of reducing NL. For the case $p_{R,E} = .8$ the extent to which NL can be improved is significantly higher (except for the case of the initial cash outlay, $κ$). No such clear patterns as in Fig. 4 can be ob-
served. One can try to group the patterns as follows: for cases in which the initial cash outlay, $\kappa$, is known, organizations with a larger number of departments appear to be better off. For the remaining scenarios a lower number of departments appears to be superior to very sophisticated organizational structures (in terms of a large number of departments). In most scenarios, the highest potential for improvement is observable for cases with a relatively large number of investment alternatives.

Interestingly, as Figs. 6 and 7 point out, perfect knowledge on one or two values in the departments’ estimation process does not necessarily reduce errors in terms of a lower CL. In particular, for scenarios in which departments have a low forecasting ability ($p = .2$), perfect foresight on the capital outlay,
Collaboration and distributed investment decisions

\( \kappa \), substantially increases CL. Further, we notice that errors are particularly lowered if the number of departments operating one joint project is low (see black areas to the left hand side of each subplot in Fig. 6). Contrary, for high accuracy in the departments’ forecasts effects on error measures are scattered and low in absolute terms. However, we are able to identify that irrespective of which values are known, errors are reduced to a greater extent if the number of departments is high (see black areas to the right hand side of each subplot in Fig. 7).

5 Conclusion

Our results imply recommendations for the corporate structure (in terms of the number of departments jointly operating investment projects) with respect to an efficient coordination of distributed investment decisions. In the case of low forecasting abilities (e.g. due to hardly predictable market conditions), a low number of departments and a low number of available investment projects minimizes the ratio to which unfavorable investment alternatives are operated. However, for low forecasting abilities the compensation loss and the loss in NPV are reduced in the case of very sophisticated organizational structures (many departments) and (in most cases) a low number of available investment alternatives. This consequently indicates that, for the case of low forecasting abilities, organizations are better off if they are allowed for (extensive) cooperation in operating joint investment projects. If forecasting abilities are high with respect to the efficiency of the coordination mechanism designing the organization in a way that the extent of cooperation is kept low appears to be superior to unlimitedly allowing for cooperation.

For setups in which one or two (out of three) measures associated with investment projects are ex-ante known, we reveal a high potential for mitigating NL in the case of a low forecasting ability. This is particularly true for organizations which are designed in a way that the number of departments is low. Here, a relatively large number of investment opportunities leads to an additional increase in the mechanism’s efficiency. For the case of a high forecasting ability, results are diverse – no clear pattern can be observed. With respect to CL, it has to be noted, that ex-ante knowing the amount of money necessary to launch the investment project significantly increases the basis for the departments’ variable compensation component. Thus, for organizational departments, the mechanism provides incentives to focus particularly on forecasting the initial cash outlay. With respect to NL, better forecasts of the initial cash outlay result in a significant increase in the mechanisms’ efficiency, too.
References