On the robustness of coordination mechanisms for investment decisions involving 'incompetent' agents

Stephan Leitner and Doris A. Behrens

Abstract In this paper we transfer the concept of the competitive hurdle rate (CHR) mechanism introduced by Baldenius et al. [2] into an agent-based model, and test its robustness with respect to an occurrence of errors in forecasting. We find that our CHR born mechanism is most robust for highly diversified investment alternatives and a limited amount of those projects in need of scarce financial support. For misforecasting both the cash flow time series and the managers' individual efficiencies of operating investment projects, we find that this result reverses with an increasing extent of being wrong, so that a lower level of project heterogeneity appears to be more advantageous than a highly diversified investment landscape, i.e., if managers are really, really wrong about future economic development, the company fares better (or less worse, to be precise) if the investment alternatives are less dissimilar. This investigation allows to quantify the extent of error, when this comes about. Moreover, we provide policy advice for how an organization could design the framework of the CHR born mechanism so that forecasting errors, which inevitably occur, bring only minimal damage to the company.

Key words: Robustness; Coordinating investment decisions; Distributed decision-making; Competitive hurdle rate; Agent-based simulation

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1 Introduction and research question

It seems to be common knowledge that a corporate investment project should only be funded, if its internal rate of return exceeds some predetermined level, often called hurdle rate for obvious reasons. Nonetheless, research on how to appropriately pin down such a rate is rare. A remarkable exception comes from Baldenius, Dutta, and Reichelstein [2], who propose the competitive hurdle rate (CHR) mechanism for efficiently coordinating corporate investment decisions of multidivisional organizations with decentral decision-making taking account of multiple and often conflicting objectives. Their mechanism is designed in a market-like way (similar to a second price auction), and is particularly designed for optimally allocating scarce financial resources: Based on forecasts of essential project characteristics (initial cash outlay, cash flow series) and estimates of individual efficiencies of carrying out projects, an organization's central office announces individualized capital costs (which depend, among others, on the extent of intraorganizational competition for tight investment budgets, cf. [9]). Based on these costs of capital, department managers autonomously decide whether or not to implement the projects they presented to the central office in order to receive funding. The corresponding incentive system is set up such that exclusively efficient decisions, i.e., decisions that maximize the organization's shareholder value, are initiated.

Baldenius et al. [2] derive their CHR mechanism from an agency model, which incorporates some restrictive assumptions. Axtell [1] summarizes these assumptions as neoclassical sweetspot: full rationality, agent homogeneity, non-interactiveness, but also the availability of highly specific information [9]. Therefore, Eisenhardt [5] already dropped the subject that agency models are sometimes inappropriate for applications in the context of organizations, and Hendry [7] argues, moreover, that agents might not always be fully competent to achieve their objectives. I.e., also if agents undertake relatively simple tasks, following [7] they potentially make errors due to bounded rationality, limitations in foresight, and rational understanding [15, 7, 13]. Employing an agentization approach [6], we take account of these issues and transfer the concept behind the CHR mechanism introduced in [2] into an agent-based model.

Our agent-based model differs from Baldenius et al. [2]'s agency model along two essential lines. First, with respect to the agents' behavioral patterns, we follow Hendry [7], and model department managers such that they may be wrong when forecasting an investment alternative's main characteristics (initial cash outlay, cash flow time series), but also when they anticipate their own efficiency of operating a project. Second, since it has been widely discussed that the assumption of 'fully informed agents' might often be inappropriate to sufficiently epitomize actual human behavior in an organizational context (e.g., [5]), we additionally limit the agents' as well as the principal's information bases.

2 The simulation model

In our model, 'agents' correspond to *managers* or *department heads*, and the 'principal' to a *central office* z that is in charge of coordinative tasks and budget allocation. Each department's head j ($j = 1, ..., m$) is instructed to submit project proposals to the central office z, where a project's durableness is limited to T. Discovering a project is modeled as drawing an investment alternative i ($i = 1, ..., n$) from a randomly generated investment landscape (see, e.g., [12, 11]) that is characterized by an initial cash-outlay, κ_i (uniformly distributed in the interval $[\underline{\kappa}, \overline{\kappa}]$) and a cash-flow time series, $c_{it}/\sum_{\tau=1}^{T} c_{i\tau}$ for $t = 1, .., T$ (c_{it} uniformly distributed in the unit interval). Moreover, the parameter η_i (uniformly distributed in $[\underline{\eta}, \overline{\eta}]$) defines i's profitability (e.g., i's return on investment), which is measured as a percentage of initial cash outlay, κ_i. Given the investment landscape's characteristics, for each investment alternative i the achievable cash-flow for time period t, thus, results in

$$\chi_{it} = \frac{\kappa_i \eta_i c_{it}}{\sum_{\tau=1}^{T} c_{i\tau}} \ . \tag{1}$$

In the model introduced by [2] agents are endowed with perfect foresight, and information regarding the alternative investment projects i is available for all managers j and the central office z. In the model presented here, we assume that decision makers are bounded rational and that each manager has information only on investment alternative that were discovered by himself or herself. The latter corresponds to disjointed information spaces as indicated by the dashed boxes in Fig. 1. Without loss of generality, we assume that a manager only submits the investment alternative that intra-departmentally scores highest. Then i denotes the sole project proposal and j stands for the manager proposing it, and we limit ourselves to the notion of i representing both the project submitted and the person who intends to carry it out. Then n and m also coincide, and we stay with the notion of n to indicate both the number of department heads and the number of serious project proposals.

When forecasting the main indicators of their projects, managers may be wrong [7]. We assume these non-systematical errors to be normally distributed with mean 0 and variance σ^2, and adjoin them multiplicatively to the undistorted values of the project indicators. Then,

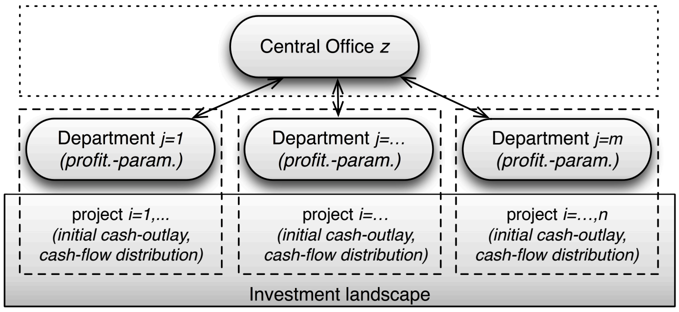
$$\hat{\kappa}_i := \kappa_i \left(1 + \epsilon_{\kappa i}\right), \tag{2}$$

with $\epsilon_\kappa \in \mathcal{N}\left(0, \sigma_\kappa^2\right)$, represents manager i's erroneous forecast of project i's initial cash-outlay. Correspondingly, manager i's error in observing the achievable cash-flow for period t is included in

$$\hat{\chi}_{it} := \chi_{it} \left(1 + \epsilon_{\chi it}\right), \tag{3}$$

with $\epsilon_\chi \in \mathcal{N}\left(0, \sigma_\chi^2\right)$.

Fig. 1: Overview of the model with 'incompetent' agents



In the model presented here, we assume that managers are characterized by an efficiency of operating projects. Manager i's efficiency in carrying out a project, ρ_i (uniformly distributed in the interval $[\underline{\rho}, \overline{\rho}]$), is expressed as a fraction of the forecasted achievable cash-flows generated by project i. Since we consider departmental managers as being unable to come up with correct forecasts, the resulting error has to be taken into account, yielding

$$\hat{\rho}_i := \rho_i \left(1 + \epsilon_{\rho i}\right), \tag{4}$$

with $\epsilon_\rho \in \mathcal{N}\left(0, \sigma_\rho^2\right)$.

The estimates $\hat{\kappa}_i$, $\hat{\chi}_{it}$, and $\hat{\rho}_i$ are next reported to the central office z (indicated by the solid arrows in Fig. 1), where z's information space is restricted to the managers' forecasts (indicated by the dotted box in Fig. 1).[1] Based on these, the central office calculates all projects' net present values (NPV),

$$\hat{\Lambda}_i = \sum_{t=1}^{T} \frac{\hat{\chi}_{it}\hat{\rho}_i}{(1+r)^t} - \hat{\kappa}_i, \quad i = 1, ..., n, \tag{5}$$

where the parameter r represents the corporation's cost of capital. For each project i, z then computes a reference NPV, i.e., the highest NPV of all projects other than i, $\hat{\Lambda}^*_{-i} = max\{\hat{\Lambda}_1, ..., \hat{\Lambda}_{i-1}, \hat{\Lambda}_{i+1}, ..., \hat{\Lambda}_n\}$. Based on $\hat{\Lambda}^*_{-i}$, for every project i the central office individually calculates a capital charge rate, r^*_i, and reports it to manager i. These *hurdle rates* are determined by exponential interpolation as they are implicitly defined by

$$\sum_{t=1}^{T} \frac{\hat{\chi}_{it}\hat{\rho}^*_i}{\left(1 + r^*_i\right)^t} - \hat{\kappa}_i = 0, \tag{6}$$

[1] Note that agency problems are excluded in the approach presented here. Thus, any deliberate misreporting by the departmental management can be ignored. Agents are incompetent but honest.

with

$$\hat{\rho}_i^* := \hat{\rho}_i \cdot \frac{\hat{\Lambda}_{-i}^*}{\hat{\Lambda}_i} \tag{7}$$

being the level of efficiency for which manager i's project is at least as profitable as any of the other $n-1$ managers' projects (cf. also [2]). Whenever a departmental manager puts a proposed project into action, in every period t he or she is charged according to the relative benefit depreciation rule for the initial cash-outlay, κ_i, using the hurdle rate, r_i^*, as discount factor.[2] It then follows that residual income during time period t results in $\pi_{it} = \chi_{it} \cdot (\rho_i - \hat{\rho}_i^*)$ ([2], p. 850, cf. also [9]).

A manager is rewarded a fixed and a variable compensation component. The latter is determined by a function of residual income, $f(\pi_{it})$. The managers aim at maximizing the discounted stream of future variable compensation components. We assume that they discount at the principal's cost of capital, r. Based on the levels of the hurdle rates, managers decide whether or not to carry out their proposals, yielding the following decision-making rule (1 corresponds to 'invest', 0 corresponds to 'do not invest'),

$$I_i = \begin{cases} 1, & \text{if } \sum_{t=1}^{T} \frac{\hat{\chi}_{it}\hat{\rho}_i}{(1+r_i^*)^t} - \hat{\kappa}_i > 0 \\ 0, & \text{otherwise.} \end{cases} \tag{8}$$

Equation 8 implies that investment is attractive for only *one* project/manager.[3] Note that the computation of the hurdle rate is based on forecasted project indicators. Thus, the project finally realized may not necessarily be the one that is optimal seen from the central office's point of view.[4] This is caused by the managers' 'incompetence' and the central office's limited access to information that is free of errors.

3 Simulation experiments and data analysis

Christensen and Knudsen ([4], p. 84) propose that '*it is necessary to pursue research on the correlation between the economic context (project distribution), individual ability, and decision-making structure*'. We take note of this and, thus, parameterize the simulation model presented in the last section in the following way. First, we deal with project distribution by modeling organizations with diversified levels of project heterogeneity, $\mathcal{H}$, where we define

[2] According to Rogerson [14], the relative benefit depreciation schedule at time t is calculated according to: $\frac{\hat{\chi}_{it}}{\sum_{\tau=1}^{T}(1+r_i^*)^{-\tau}\hat{\chi}_{i\tau}}$.

[3] Note that the optimization problem of manager i results in $\sum_{t=1}^{T} \frac{f(\pi_{it})}{(1+r)^t} \to max!$

[4] Considering the limitation of financial resources, the central office's optimization problem can be formalized as $\sum_{t=1}^{T} \frac{\chi_{it}\rho_i}{(1+r)^t} - \kappa_i - \sum_{t=1}^{T} \frac{f(\pi_{it})}{(1+r)^t} \to max!$ for $\sum_i^n I_i = 1$.

$\mathcal{H} := \overline{\eta} - \underline{\eta}$. Thus, the higher $\mathcal{H}$ is, the more heterogenous is the investment landscape with respect to the projects' profitabilities, η_i, *ceteris paribus*. We fix the interval's lower boundary, $\underline{\eta}$, at 1.5 and vary the interval's upper boundary, $\overline{\eta}$, from 2.5 to 4.0 in steps of 0.5. Second, we investigate individual inabilities by varying the standard deviations of all possible forecasting errors from 0.05 to 0.3 in steps of 0.05. Third, we focus on the organizational rather than on decision-making structure. In particular, we investigate the degree of intra-organizational competition for scarce investment resources by varying the number of departments/managers/projects from $n = 2$ to $n = 6$ in steps of 2. All other parameters are kept constant, i.e., the assets' durableness, T, is fixed at 3; the central office's cost of capital, r, is set to 0.1; the initial cash outlay, κ_i, is drawn from $\mathcal{U}(100{,}000, 110{,}000)$; manager i's efficiency parameter, ρ_i, is drawn from $\mathcal{U}(0.80, 0.85)$. Considering all variations in the parameterization of the model, for each forecasting error $4 \times 6 \times 3 \times 3$ scenarios are investigated. For each scenario, we execute $80,000$ simulation runs. Thus, the presented results are based on 1.728×10^7 simulations in total.

Let the project eventually put into action by the manager having proposed it to the central office be denoted by $\mathbb{i} := \{i | \sum_{t=1}^{T} \hat{\chi}_{it} \cdot \hat{\rho}_i \cdot (1 + r_i^*)^{-t} - \hat{\kappa}_i > 0\}$, and the optimal project be given by $i^* := \{i | max_i (\sum_{t=1}^{T} \chi_{it} \cdot \rho_i \cdot (1+r)^{-t} - \kappa_i)\}$.[5] In order to express the robustness of our CHR mechanism with respect to the managers' 'incompetence', we report two measures, i.e., the probability of operating suboptimal projects,

$$\tilde{P} := \mathbb{P}[\, \mathbb{i} \neq i^*] \,, \tag{9}$$

and the foregone NPV to be expected,

$$\tilde{\Lambda} := \frac{1}{D} \sum_{d=1}^{D} \hat{\Lambda}_{\mathbb{i}}^{d} - \Lambda_{i^*}^{d} \,, \tag{10}$$

where the superscript d (d=1, ..., D) indicates the simulation run. According to Eq. 5, $\Lambda_{i^*}^{d} = \sum_{t=1}^{T} \chi_{i^* t} \cdot \rho_{i^*} \cdot (1+r)^{-t} - \kappa_{i^*}$, represents the shareholder value maximizing investment project for simulation run d.

4 Results

From our simulation experiments, we gain some interesting insights about the drawbacks of distorted forecasts on the way the CHR mechanism is capable of sucessfully coordinating investment decisions. First of all, we find that errors in forecasting a manager's efficiency of operating a project (cf. Tab. 3) lead

[5] The selection of the finally realized project, $\mathbb{i}$, is based on forecasted values, while the shareholder value maximizing project, i^*, is determined on the basis of undistorted values.

to the highest observed levels of distortion, followed by errors in forecasting the cash flow time series (cf. Tab. 1), and errors in forecasting the initial cash outlay (cf. Tab. 2). Most of the results presented in Tabs. 1 – 3 are significant in terms of confidence intervals (with $\alpha = 0.01$).

For errors in forecasting the cash flow time series and errors in forecasting the efficiency parameter, similar patterns are observed: For the case that errors are distributed with a low standard deviation, σ, increasing the level of heterogeneity, $\mathcal{H}$, leads to an increase in the level of the expected foregone NPV.[6] The opposite is observed for high standard deviations, where the absolute value of the expected foregone NPV, $|\tilde{\Lambda}|$, increases with increasing $\mathcal{H}$. Thus, a 'point of inflexion', denoted by $\mathcal{P}$, occurs. I.e., to minimize the odd effects of forecasting errors, for $\sigma > \mathcal{P}$ we find that lower $\mathcal{H}$-values should be preferred over higher $\mathcal{H}$-values. Moreover, our results indicate that the 'point of inflexion' shifts into the direction of larger σ-values, if the number of serious project proposals, n, increases.

Table 1: Forecasting error cash flow time series, $T = 3$

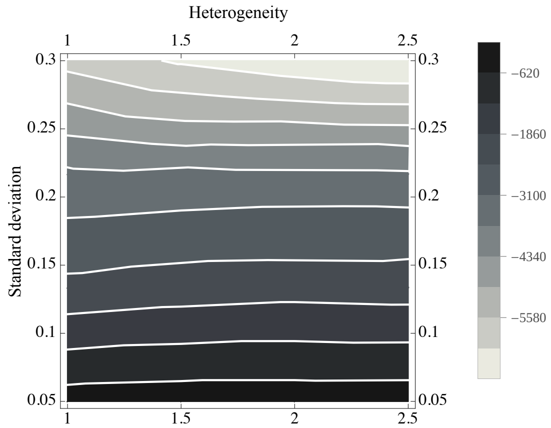
Expected foregone NPV, $\tilde{\Lambda}$ / *Probability,* $\mathbb{P}[\mathbb{i} \neq i^*]$

	Expected foregone NPV, Heterogeneity $\mathcal{H}$				Probability, Heterogeneity $\mathcal{H}$			
Std.dev. σ	1.00	1.50	2.00	2.50	1.00	1.50	2.00	2.50
Number of departments, $n = 2$								
0.05	-330.22	-282.89	-282.66	-272.58	0.0669	0.0504	0.0441	0.0386
0.10	-1,190.88	-1,055.56	-1,027.57	-1,010.13	0.1285	0.0982	0.0844	0.0737
0.15	-2,322.48	-2,172.86	-2,086.42	-2,134.90	0.1788	0.1422	0.1191	0.1073
0.20	-3,586.39	-3,533.76	-3,472.67	-3,498.66	0.2234	0.1814	0.1549	0.1380
0.25	-4,759.82	-4,852.44	-5,002.83	-5,183.01	0.2589	0.2125	0.1856	0.1690
0.30	-5,790.79	-6,280.71	-6,606.45	-6,874.11	0.2906	0.2424	0.2124	0.1942
Number of departments, $n = 4$								
0.05	-724.96	-700.37	-712.69	-707.28	0.0687	0.0554	0.0483	0.0442
0.10	-2,383.19	-2,357.29	-2,407.91	-2,476.02	0.1225	0.1016	0.0887	0.0811
0.15	-4,421.53	-4,414.96	-4,644.23	-4,780.80	0.1642	0.1374	0.1219	0.1121
0.20	-6,415.74	-6,655.18	-7,178.27	-7,344.25	0.1964	0.1659	0.1516	0.1376
0.25	-8,308.67	-8,810.05	-9,475.23	-10,170.13	0.2212	0.1902	0.1728	0.1608
0.30	-9,851.29	-11,013.01	-11,914.18	-12,934.46	0.2386	0.2102	0.1913	0.1802
Number of departments, $n = 6$								
0.05	-1,053.85	-1,004.92	-1,049.40	-1,106.03	0.0651	0.0522	0.0472	0.0434
0.10	-3,196.61	-3,252.72	-3,393.48	-3,567.55	0.1097	0.0929	0.0828	0.0767
0.15	-5,472.97	-5,841.79	-6,202.06	-6,678.08	0.1409	0.1219	0.1105	0.1032
0.20	-7,704.43	-8,310.50	-9,046.58	-9,850.64	0.1624	0.1431	0.1313	0.1235
0.25	-9,648.74	-10,735.66	-11,699.64	-12,814.45	0.1790	0.1594	0.1472	0.1396
0.30	-11,432.43	-12,884.80	-14,325.73	-15,672.88	0.1908	0.1720	0.1607	0.1516

Above findings are due to the fact that relatively small errors do *not* cause any reranking of the proposed projects. Relatively large errors lead, however, more frequently to project proposals being wrongly reranked with respect to their contributions to shareholder wealth. Increases in project heterogeneity,

[6] Note that measured in absolute terms, the expected foregone NPV decreases.

Fig. 2: Forecasting error in cash flow time series ($n = 2$)



$\mathcal{H}$, imply that the ‘differences’ between the projects become larger. In contrast, relatively small σ-values do not affect the ranking if projects are ‘very different’, which is why the errors’ undesired effects decrease with increases in $\mathcal{H}$. In contrast, relatively large σ-values ‘overcome the differences’ between projects, which leads to an increase of the (absolute value of) expected foregone NPV, $|\tilde{\Lambda}|$. In order to illustrate the matter, let us outline an example (cf. Tab. 1, $n{=}2$): For a low standard deviation, i.e., $\sigma{=}0.05$, $|\tilde{\Lambda}|$ computed for errors in forecasting the cash flow time series decreases from 330.22 to 272.58 as the degree of heterogeneity, $\mathcal{H}$, increases from 1.0 to 2.5. A reversal of this pattern can be observed for $\sigma = 0.25$, where the absolute value of the expected foregone NPV begins to increase with increases in $\mathcal{H}$, i.e., for $\sigma = 0.25$ and $\mathcal{H} = 1.0$, $|\tilde{\Lambda}| = 4,759.82$. As $\mathcal{H}$ increases to 2.5, the absolute value of the expected foregone NPV increases to $5,183.01$.

For the probability of operating a suboptimal project, we find that it decreases with increases in project diversity, $\mathcal{H}$. According to Leitner and Behrens [10], similar patterns for the foregone NPV as well as for $\tilde{P}$ can be observed for variations in assets’ useful life, T. For errors in the forecasts of a manager’s efficiency of operating a project as well as for misforecasts of the cash flow time series, this allows us to conclude that our implementation of the CHR mechanism is most robust for small n- and high $\mathcal{H}$-values. Also computing the expected values of the foregone NPV (i.e., $|\tilde{\Lambda}| \cdot \tilde{P}$) allows for this conclusions. The pattern which can be observed for errors in forecasting cash flow time series is sketched in Fig. 2. Apart from the magnitude of foregone NPVs, errors in forecasting the efficiency of operating projects lead to a very similar pattern as misforecasting cash flow time series does.

For forecasting errors of the initial cash outlay, within the investigated ranges of $\mathcal{H}$ and σ (cf. Tab. 2), our results indicate that the absolute level

Table 2: Forecasting error initial cash outlay, $T = 3$

Expected foregone NPV, $\tilde{\Lambda}$

	Std.dev. σ	Heterogeneity $\mathcal{H}$ 1.00	1.50	2.00	2.50
Number of departments, $n = 2$					
	0.05	-276.46	-190.66	-153.29	-114.87
	0.10	-1,017.11	-725.95	-566.92	-452.02
	0.15	-2,018.40	-1,537.15	-1,202.33	-1,002.13
	0.20	-3,182.31	-2,553.49	-2,032.42	-1,711.97
	0.25	-4,319.18	-3,599.93	-2,990.41	-2,541.71
	0.30	-5,401.91	-4,763.03	-4,051.50	-3,447.66
Number of departments, $n = 4$					
	0.05	-518.34	-368.80	-268.47	-229.95
	0.10	-1,890.86	-1,360.08	-1,066.37	-876.59
	0.15	-3,715.01	-2,838.75	-2,259.48	-1,871.08
	0.20	-5,752.25	-4,576.42	-3,798.56	-3,111.43
	0.25	-7,650.25	-6,611.13	-5,508.97	-4,732.70
	0.30	-9,649.57	-8,665.24	-7,557.49	-6,459.94
Number of departments, $n = 6$					
	0.05	-283.94	-192.97	-145.91	-116.56
	0.10	-1,012.94	-721.36	-547.18	-467.05
	0.15	-2,021.23	-1,485.19	-1,195.72	-989.72
	0.20	-3,188.82	-2,522.01	-2,022.43	-1,668.80
	0.25	-4,260.87	-3,593.90	-2,998.51	-2,578.79
	0.30	-5,342.65	-4,754.71	-4,078.54	-3,453.13

Probability, $\mathbb{P}[\mathbb{i} \neq i^*]$

Heterogeneity $\mathcal{H}$ 1.00	1.50	2.00	2.50
0.0624	0.0426	0.0337	0.0260
0.1199	0.0836	0.0649	0.0506
0.1659	0.1209	0.0925	0.0760
0.2132	0.1551	0.1206	0.0986
0.2474	0.1855	0.1442	0.1205
0.2789	0.2123	0.1693	0.1401
0.0578	0.0407	0.0298	0.0252
0.1085	0.0770	0.0599	0.0486
0.1497	0.1099	0.0861	0.0704
0.1846	0.1368	0.1107	0.0898
0.2105	0.1633	0.1320	0.1100
0.2332	0.1845	0.1527	0.1276
0.0545	0.0385	0.0297	0.0234
0.0967	0.0708	0.0559	0.0459
0.1284	0.0978	0.0784	0.0656
0.1532	0.1194	0.0977	0.0828
0.1711	0.1387	0.1149	0.0979
0.1874	0.1531	0.1297	0.1116

of foregone NPV, $|\tilde{\Lambda}|$, decreases with increases in the project diversity, $\mathcal{H}$. Up to a σ-level of 0.3 we do not observe a 'point of inflexion', as is the case for the two other types of errors. What is, however, in line with the errors in forecasting a manager's efficiency and the cash flow series: The probability to operate a suboptimal project decreases with increases in $\mathcal{H}$. Moreover, our results suggest that the difference between the absolute values of the forgone NPV in the case of $\mathcal{H} = 2.5$ and $\mathcal{H} = 1.0$ increases with increasing σ. This indicates that potentially there exists a 'point of inflexion' for higher σ-values. Nonetheless, increasing the standard deviation would lead to unrealistically high errors.[7] The pattern which can be observed for misforecasting the initial cash outlay is delineated in Fig. 3.

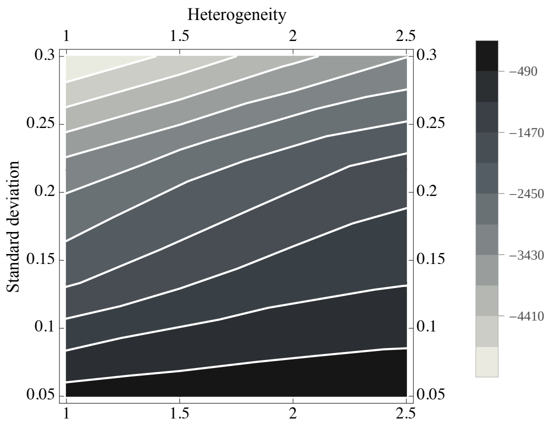
To sum up our results: homogenous investment alternatives are less robust to forecasting errors than investment landscapes that are characterized by a higher level of project diversity. For errors in forecasting the initial cash outlay, this finding is independent from the extent of being wrong, σ, and the number of serious project proposals, n. For misforecasting a manager's efficiency parameter and a project's cash flow series, we observe a 'point of inflexion', which, with increases in n, shifts towards larger σ-values. For σ-values $< \mathcal{P}$, higher $\mathcal{H}$-values are to be preferred over lower levels of heterogeneity. For σ-values $> \mathcal{P}$ the opposite is true.

[7] Notice that an error which is ≥ 1 would render the initial cash outlay to a cash inflow, which is far away from reality.

Table 3: Forecasting error departmental efficiency, $T = 3$

	Foregone NPV, $\tilde{A}$				Probability, $\mathbb{P}[\mathbb{i} \neq i^*]$			
	Heterogeneity $\mathcal{H}$				Heterogeneity $\mathcal{H}$			
Std.dev. σ	1.00	1.50	2.00	2.50	1.00	1.50	2.00	2.50
Number of departments, $n = 2$								
0.05	-732.64	-633.90	-616.30	-605.71	0.1008	0.0765	0.0651	0.0579
0.10	-2,442.38	-2,232.00	-2,131.93	-2,161.88	0.1852	0.1446	0.1205	0.1089
0.15	-4,300.98	-4,400.32	-4,352.38	-4,428.46	0.2444	0.2010	0.1743	0.1552
0.20	-5,911.91	-6,335.79	-6,839.38	-7,127.53	0.2916	0.2436	0.2168	0.1989
0.25	-7,206.81	-8,344.47	-9,064.68	-9,727.46	0.3256	0.2818	0.2535	0.2330
0.30	-8,245.10	-9,858.64	-11,075.46	-12,156.77	0.3529	0.3110	0.2802	0.2613
Number of departments, $n = 4$								
0.05	-1,545.19	-1,464.90	-1,511.47	-1,524.81	0.1003	0.0800	0.0710	0.0635
0.10	-4,541.71	-4,627.56	-4,717.46	-4,975.51	0.1674	0.1402	0.1236	0.1136
0.15	-7,530.51	-7,953.67	-8,544.26	-8,932.54	0.2117	0.1798	0.1646	0.1497
0.20	-10,037.87	-11,264.49	-12,119.05	-13,180.33	0.2406	0.2138	0.1933	0.1829
0.25	-12,120.89	-14,052.76	-15,588.19	-17,039.86	0.2630	0.2344	0.2181	0.2043
0.30	-13,686.27	-16,398.51	-18,397.32	-20,474.77	0.2777	0.2521	0.2326	0.2236
Number of departments, $n = 6$								
0.05	-2,139.60	-2,133.04	-2,210.07	-2,305.38	0.0912	0.0761	0.0682	0.0620
0.10	-5,610.86	-6,014.24	-6,410.39	-6,785.39	0.1431	0.1243	0.1129	0.1048
0.15	-8,952.02	-9,804.65	-10,684.70	-11,781.61	0.1739	0.1538	0.1423	0.1352
0.20	-11,503.24	-13,271.66	-14,655.92	-15,992.54	0.1921	0.1749	0.1621	0.1545
0.25	-13,649.69	-15,987.27	-18,227.56	-20,167.55	0.2052	0.1882	0.1784	0.1694
0.30	-15,293.43	-18,398.87	-21,002.57	-23,606.16	0.2144	0.1990	0.1884	0.1816

Fig. 3: Forecasting error in initial cash outlay ($n = 2$)



This allows for providing some important policy advice: in the short run, the level of project heterogeneity can be regarded as an element of choice, i.e., the corporation can, for example, toughen the minimum requirements with respect to profitability that intended projects have to fulfill in order to be accepted as a proposal for funding—and, at the same time, limit project diversity. If, in addition, the central office has knowledge on the extent of ‘departmental incapability’, the contour plots given in Figs. 2 and 3 may constitute a solid basis, if one has to come up with the decision about when to narrow down the level of project diversity in order to minimize the effects of incorrect forecasts. However, it has to be kept in mind that, besides minimizing the errors’ effects, limiting the level of heterogeneity also limits the corporation’s future development potential (cf. also [9]).

5 Concluding remarks

In this paper we discribe how we transfer the concept of the competitive hurdle rate (CHR) mechanism, which is introduced by Baldenius, Dutta, and Reichelstein [2] to achieve efficient budget allocation, into an agent-based model, and test the robustness of our CHR born mechanism with respect to errors in forecasting. We find that the robustness of the mechanism critically depends on two parameters: the level of project diversity, and the number of project proposals. The CHR mechanism turns out to be most robust for a high level of heterogeneity, and a relatively low number of projects competing for scarce funding. For errors in forecasting the cash flow time series, and the managers’ efficiencies in operating projects, we find that with increases in the extent of error, this finding reverses, so that a lower level of heterogeneity appears to be beneficial over a diverse investment landscape. For organizations, the level of heterogeneity is an important policy parameter that allows for dampening the negative effects of forecasting errors. We provide policy advice for how to design framework conditions, so that forecasting errors lead to a minimal magnitude of foregone net present value (NPV).

Our simulation model might be extended in the following ways: the investigation of more than one error at a time would give important insights into how to efficiently design framework conditions for coordinating investment decisions. Thus, the effect of combinations of errors is one potential avenue for future research (for research on the combination of errors cf., for example, [3, 8]). For some of our variables, we assume a uniform distribution. Future research might test whether the assumptions regarding the distributions affect the results. Moreover, communication among agents is assumed to be cut off. As some local interactions could positively affect the forecasting quality (cf., [16, 17]), one further promising avenue for future research would be to complement the model by intraorganizational communication within a network structure.

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