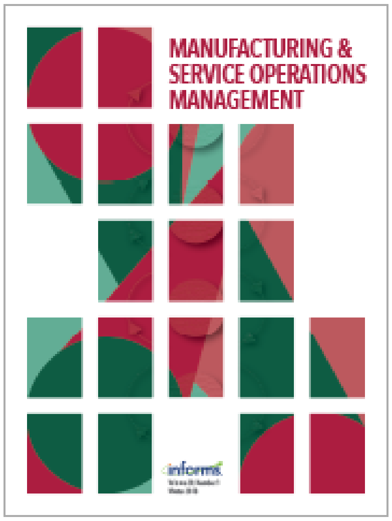

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Project Portfolio Selection with Strategic Buckets—The Role of Naïve Diversification

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Abstract. ***Problem definition*:** A company's project portfolio is an important success factor. Employing strategic buckets to segment the overall budget into budgets for different project types is a commonly used approach for managing project selection. Strategic buckets typically refer to sets of projects of a certain type, such as safe and risky projects. A strategic bucket specification defines the number of buckets and thresholds between them. This paper addresses the question of how different strategic buckets specifications affect decision makers' project selection behavior. ***Methodology/results*:** We develop a behavioral model of the effect of strategic buckets on project selection and use laboratory experiments to analyze how bucket specifications affect project selection decisions. For various strategic bucket specifications where a rational decision maker would allocate the budget to projects of the project type matching their risk preference only, we find that actual decision makers have the tendency to allocate the budget evenly among buckets and among project types within buckets. This observation can be explained by the naïve diversification bias, and we observe this effect in experimental settings with different selection processes, project definitions, and subject pools. ***Managerial implications*:** Our findings allow companies to better understand the effect of buckets guidelines on actual project selection behavior and to manage their project portfolio selection by choosing the right bucket specification.

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Keywords: project selection • strategic buckets • naïve diversification • information asymmetry

1. Introduction

Managing a company's project portfolio is important for corporate strategy implementation (Chao and Kavadias 2008). Ideally, the projects that are selected by management result in a project portfolio that optimizes the corporation's overall objective. However, if decision makers are prone to decision biases, the project selection can be suboptimal. A survey that McKinsey & Company conducted among more than 1,000 executives about investment-related decisions (McKinsey 2013) suggests that a mismatch between corporate goals and actual project selection behavior is not uncommon. The participants of the survey were asked about the projects' risk levels at their companies. Only 38% considered risk levels as appropriate, 45% considered risk levels too low, and 16% of participants reported risks levels to be too high.

An observation that one of the coauthors made at a globally operating conglomerate illustrates a potential mitigation of this issue. The conglomerate's headquarters initially left the project selection up to the business units' management. This approach resulted in too conservative investments from the corporate perspective, and the management criticized the reluctance of local managers to also allocate budgets to high-risk and high-expected-return projects. As a consequence, they changed their reporting guidelines and requested their business units to also report budgets allocated to high-risk and high-expected-return projects. This change in reporting guidelines led to an increase in the business units' investment in high-risk projects.

The conglomerate mentioned above specified a guideline that requires business units to report the investment in certain project types. Similarly, companies can specify project selection guidelines to align project selection decisions with other corporate objectives. The approach of classifying projects and allocating budgets to specific project types has been addressed in the project management literature on strategic buckets (Cooper 2006, Chao and Kavadias 2008), where explicit categories of project types are defined and budgets are set for each of these strategic buckets.

Although these project portfolio management approaches typically assume rational management decisions, a rich body of literature outside the field of project portfolio management demonstrates that this assumption does not necessarily hold in practice. For example, when individuals make portfolio decisions regarding their private investment plans, they have the tendency to diversify investment across all available investment options, even if it is not in their best interest. Thaler (1999) explains this behavior by mental accounting, where individuals build mental budgets for different mental accounts, and naïve diversification, where people allocate resources evenly among mental accounts. Obviously, project portfolio management consisting of binary management decisions on whether to initiate a project differs from continuous private decisions in financial portfolios that can usually be easily altered. Still, similar behavioral mechanisms might apply, and project portfolio managers might be prone to a naïve diversification bias. Naïve diversification would lead to spreading investments evenly across strategic buckets as well as across project types within strategic buckets.

To the best of our knowledge, the interplay between naïve diversification bias and strategic buckets in project management has not been addressed. Defining a bucket specification as the number of buckets and the thresholds between them, our paper addresses the following research question. What are the consequences of different strategic buckets specifications? We consider different project types based on expected return and risk, and we analyze the budget share invested in those project types for different strategic bucket specifications. Knowing about naïve diversification effects helps managers not only to better understand own potential biases, but also design strategic buckets to nudge employees to select project portfolios that better align with corporate strategy.

The structure of our paper is as follows. Based on the existing literature (Section 2), we propose a model for project selection under strategic buckets (Section 3). We test the model in a series of experimental studies for project types characterized by expected returns and risk levels (Section 4). We first explore naïve diversification behavior without strategic buckets by analyzing how people allocate budgets to a set of projects with different risk-return profiles. We observe that people have a tendency to spread budgets across more project types than risk and return considerations suggest. We then analyze strategic buckets where project types are classified and assigned to different buckets and where subjects can choose the budget that they allocate to each strategic bucket and within each bucket. Our treatments differ in specification of buckets: that is, the number of buckets and the thresholds between them. We observe that people have the tendency to naïvely allocate budgets both between and within strategic buckets. Our main study was carried out with a student subject pool in a university laboratory, projects were selected sequentially, and realized project values were drawn from a continuous distribution. Our robustness study (Section 5) was executed with a more diverse online subject pool, projects were selected simultaneously, and realized project values were drawn from a binary distribution (successful versus failed projects). We find that our results also hold for different subject pools, selection processes, and project definitions. Finally, we discuss implications of our research for companies that use or intend to use strategic buckets to manage their project portfolio (Section 6). Companies using strategic buckets should be aware that their managers are probably prone to a naïve diversification bias and anticipate this behavior. They should also be aware of their own potential naïve diversification biases.

2. Related Literature

Our research addresses the question of how naïve diversification affects project selection when strategic buckets are employed. We next discuss the literature on strategic buckets in project selection and then provide an overview of the literature on the naïve diversification bias.

2.1. Project Selection and Strategic Buckets

A large body of literature discusses different aspects of investment decisions under uncertainty with a focus on risk preferences of decision makers (Dow and da Costa Werlang 1992): for example, when managing innovation projects (Loch 2017). The Product Development and Management Association regularly conducts surveys on best practices in new product development (Page 1993), in which the management of project portfolios' risk levels is consistently mentioned. One option to manage a project portfolio's risk level is implementing strategic buckets—"earmarking buckets of resources … targeted at different project types" (Cooper et al. 2004, p. 51). In the survey by

Markham and Lee (2013), strategic buckets turned out to be a portfolio tool often used by successful companies.

A theoretical framework on "when and how to use strategic buckets" was proposed by Chao and Kavadias (2008). They state normative models to determine strategic buckets for "revolutionary" projects depending on environmental complexity (such as the number of unknown technological interdependencies), environmental stability (such as the probability of market disruptions), and competition intensity (such as the probability of firm extinction). Deviations from optimal decision making, such as bounded rationality, are mentioned, but behavioral biases are not addressed by their models.

A different view on strategic buckets is taken by Hutchison-Krupat and Kavadias (2015), where the tradeoff between top-down and bottom-up approaches in strategic resource allocation is discussed. They argue that executives could install a strategic bucket policy that combines advantages of top-down and bottom-up approaches. An analytical analysis assuming rational agents detects the most beneficial policy. Their "conceptualization of difficulty classifies initiatives into those that are difficult (that is, more radical), with a higher chance of failure, and those that are standard (that is, more incremental) and exhibit a greater chance of success" (Hutchison-Krupat and Kavadias 2015, p. 394). Instead of a binary classification, Chandrasekaran et al. (2015) classify projects into three categories: that is, radical innovation projects, incremental innovation projects, and hybrid projects that are in between those types. We analyze how project selection is affected by buckets: that is, classes of project types. Although the literature mentioned above considers a bucket approach, where the budget of each bucket is given, we study a less top-down variant of strategic buckets, where managers set bucket budgets and a company can influence project selection by changing bucket specifications.

2.2. Naïve Diversification

Research on strategic buckets typically considers rational decision makers. However, human decisions have been shown to exhibit decision biases in related settings. We expect naïve diversification to also be relevant for project portfolio selection.

Naïve diversification denotes an investment strategy where funds are evenly distributed among all possible options (Bird and Tippett 1986, Tu and Zhou 2011). The diversification heuristic as a behavioral concept was introduced to a wider audience by Thaler (1999), who includes the tendency to diversify among possible options in his mental accounting framework. Thaler (1999) discusses some seminal studies. The first demonstrations of this diversification behavior originate in the marketing domain. Simonson (1990) analyzes the differences of simultaneous versus multiple separate buying decisions on the variety of outcomes. He suggests that because of uncertainty about own preferences, choices show greater variety when being performed simultaneously compared with multiple decisions that are spread over time. Choosing variety (that is, diversifying among possible options) can thus be interpreted as a choice heuristic. In a succeeding study, Simonson and Winer (1992) demonstrate that the variety of selected options increases with the quantity of chosen products. An analysis of sales data of yogurt shows that consumers buy unusual flavors when large quantities are purchased.

Read and Loewenstein (1995, p. 46) define this behavior as diversification bias, stating that "when people choose many goods in combination they commonly choose more variety than they end up wanting." They find indications for this behavior in experimental studies by providing participants the chance to change their initial choices; those who selected several goods at once tended to reduce variety later, whereas those who selected one good at a time did not tend to increase variety. Similar observations can be found in follow-up studies (Read et al. 1999, 2001). We conclude from this stream of research that people tend to diversify more than is in their actual interest when selecting among alternatives.

A different context, asset allocation in defined contribution saving plans, is the focus of Benartzi and Thaler (2001). In a series of experiments, subjects allocated their retirement contributions to funds that consisted of bonds, stocks, or a combination of both. Independent of which funds were offered, subjects distributed their savings relatively evenly among the offered funds, leading to significant differences in the resulting portfolios. Somewhat related to our setting, Fox et al. (2005) analyze possible consequences of such behavior. In a set of experiments, they analyze the effect of grouping options on outcomes. For example, in an experiment about selecting time periods for complimentary lunches, subjects would select more slots in the future if those were partitioned into many fine intervals compared with one wide interval. The effect of naïve diversification on capital allocation to divisions in multibusiness companies is discussed in Bardolet et al. (2011). They discover that companies tend to evenly distribute resources over divisions, thus underweighting relevant factors, such as past or expected profits. In the operations management domain, Gurnani et al. (2014) find indications for naïvely diversifying among suppliers in situations where a rational decision maker should select only one specific supplier.

We conclude that there is a strong indication for the naïve diversification bias in many situations. Although the literature discussing naïve diversification biases assumes a single decision layer, project portfolio management with strategic buckets forms decision contexts with multiple layers of decisions, such as splitting a project portfolio budget into different bucket budgets and allocating the bucket budgets to different projects. Building upon the literature on the naïve diversification effect observed in other domains, we study its effect on project selection given the nested structure of strategic buckets.

3. Theory Development

In the following, we introduce the general setting and the rational prediction before we introduce a behavioral model to analyze the effect of different bucket specifications on project selection under naïve diversification. We consider project types $p \in \mathcal{P}$ that describe independent projects with certain attributes: in our case, expected returns $\mu(p)$ and risk levels $\sigma(p)$, attributes that are commonly used in project portfolio management (Loch and Kavadias 2007). We assume that project types with higher risk levels have higher expected returns and that the realized returns of projects are uncorrelated. We consider projects with the same budget requirements (normalized at $n = 1$) and a project portfolio budget of N such that the decision maker can select up to N projects. The decision variables are the expected budget share invested per project type. Our performance measures are expected portfolio return and expected portfolio risk, which we measure by the expected standard deviation (SD) of the portfolio return.

3.1. Rational Decision Making

A risk-sensitive decision maker (indicated by superscript r) (see Cohn et al. 1975, Dow and da Costa Werlang 1992, Rabin and Thaler 2001) invests budget share $s^r(p)$ in project type p in line with the decision maker's risk preference. For notational convenience, we sort project types by risk level such that project type $p = 1$ has the lowest risk level and project type $p = |\mathcal{P}|$ has the highest risk level. Note that a risk-neutral rational decision maker would only invest in projects of type $|\mathcal{P}|$ with the highest expected returns.

3.2. Strategic Buckets

We next discuss how project portfolios of naïvely diversifying decision makers are affected by the specification of buckets. We consider buckets $b \in \mathcal{B}$ ($|\mathcal{B}| > 1$) that are sets of project types with certain risk levels. We denote the project types that are associated with bucket b by $p \in \mathcal{P}_b$ and the bucket associated with project type p by $b(p)$. We refer to the project type of bucket b with the highest risk level in the bucket as bucket b's threshold p_b, with $p_0 = 1 \le p_1 < \cdots < p_{|\mathcal{B}|-1} < p_{|\mathcal{B}|} = |\mathcal{P}|$. For example, consider project types $\mathcal{P} = \{1, \ldots, 40\}$, two buckets $|\mathcal{B}| = 2$, and one threshold $p_1 = 10$ ($p_0 = 1$ and $p_2 = 40$). Then, $b(p) = 1$ for all $p \le 10$, and $b(p) = 2$ for all $p \ge 11$; that is, project types 1–10 are contained in the first bucket, and project types 11–40 are contained in the second bucket.

3.3. Naïve Diversification

A naïvely diversifying decision maker (indicated by superscript n) allocates the budget evenly between buckets (superscript β) and the bucket budgets evenly among the project types within that bucket (superscript ω). We define the expected budget share of bucket b as $s^n(b)$ and the expected budget share of project type p in bucket b as $s^n_b(p)$. The case of no strategic buckets can be defined as the special case of one bucket, where the entire project budget and all project types are assigned to this bucket. Expected budget shares (between and within buckets) are defined as follows:

$$s^{n,\beta}(b) = \frac{1}{|\mathcal{B}|}, \tag{1}$$

$$s^{n,\omega}_b(p) = \frac{1}{|\mathcal{P}_{b(p)}|}. \tag{2}$$

The expected total budget share $s^n(p)$ invested in project type p is

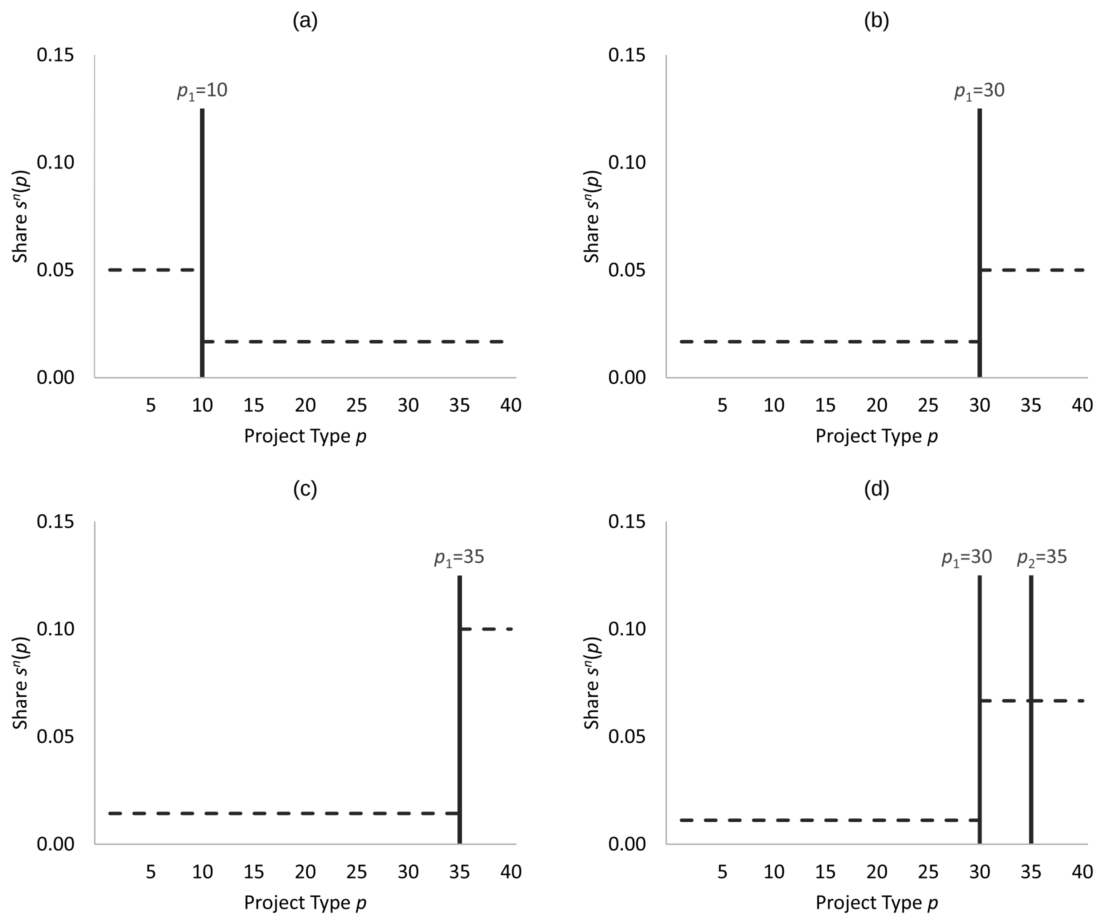
$$s^n(p) = \frac{1}{|\mathcal{B}|} \cdot \frac{1}{|\mathcal{P}_{b(p)}|}. \tag{3}$$

The following proposition states the effect of the threshold p_b between buckets b and $b+1$ on the investment decisions of a naïvely diversifying decision maker for a given number of buckets $|\mathcal{B}|$ and $1 \le b < |\mathcal{B}|$ (all proofs are contained in Online Appendix EC.1).

Proposition 1. *For higher thresholds p_b, the expected investment per project type is lower for bucket b, higher for bucket $b+1$, and unaffected for all other buckets.*

We provide an example with $N = 40$ project types, and we illustrate four different bucket specifications in Figure 1. The available project types sorted by risk level are depicted on the horizontal axes in Figure 1, and the expected budget shares per project type $s^n(p)$ of a naïvely diversifying decision maker are depicted on the vertical axes in Figure 1. Three cases with two buckets $b = 1$ (low risk) and $b = 2$ (high risk) and different threshold p_1 are illustrated in Figure 1, (a)–(c). One can observe the effect of different thresholds on the expected budget share of project types of the high-risk bucket $\mathcal{P}_2$: that is, all projects on the right side of the threshold. In Figure 1(a), this bucket includes 30 project types, leading to an expected budget share of 0.017 ($1/2 \cdot 1/30$) per project type. In Figure 1(b), having a higher threshold to include 10 project types leads to an increasing expected budget share per project type of 0.050 ($1/2 \cdot 1/10$). In Figure 1(c), the expected budget share per project type further increases to 0.100 ($1/2 \cdot 1/5$) as the high risk bucket includes only five project types.

Figure 1. Effect of Thresholds on Predicted Investment Share



Furthermore, the number of buckets may affect decisions of a naïvely diversifying decision maker. A set of project types could be assigned to two buckets (b_{I} and b_{II}) instead of to one bucket b by adding a threshold $p_{b_{\text{I}}}$ with $p_{b-1} < p_{b_{\text{I}}} < p_{b_{\text{II}}} = p_b$. We define the fraction of the new buckets (b_{I} or b_{II}) of the original bucket as $f_{b_{\text{I}}} = (p_{b_{\text{I}}} - p_{b-1})/(p_b - p_{b-1})$ and $f_{b_{\text{II}}} = (p_b - p_{b_{\text{I}}})/(p_b - p_{b-1})$. The following proposition states the effect of splitting a bucket into two buckets on the investment decisions of a naïvely diversifying decision maker for a given number of buckets $|\mathcal{B}|$ and $1 \le b < |\mathcal{B}|$.

Proposition 2. *If bucket b with threshold p_b is divided into two buckets b_{I} and b_{II}, then*

a. *the expected investment increases for project types of the original bucket b and decreases for all other project types;*

b. *the expected investment share per project type assigned to bucket b_i increases (decreases) if the fraction of the new bucket f_{bi} is smaller (greater) than $|\mathcal{B}|/(|\mathcal{B}|+1)$.*

Figure 1(d) shows a case with three buckets $b = 1$, $b = 2$, and $b = 3$. We can analyze the difference of having bucket $\mathcal{P}_2$ of Figure 1(b) with threshold $p_1 = 30$ and having an additional bucket $\mathcal{P}_3$ with $p_2 = 35$ on the expected budget share of a naïvely diversifying decision maker. In the case of the additional bucket, both subbuckets have a fraction of $f_i = 1/2$ of the single bucket. Adding the bucket leads to a higher expected budget share for the corresponding project types $\{31, \ldots, 40\}$ from a level of 0.050 $(1/2 \cdot 1/10)$ to a level of 0.067 $(1/3 \cdot 1/5)$.

Comparing Figure 1(d) with Figure 1(c) shows another example, this time comparing bucket $b = 1$ with threshold $p_1 = 35$ with the two buckets $b = 1$ and $b = 2$ with $p_1 = 30$ and $p_2 = 35$. The two buckets have the corresponding fractions of $f_2 = 6/7$ and $f_3 = 1/7$, and the investment share in the project types of the first subbucket $\{1, \ldots, 30\}$ has a lower value of 0.011 $(1/3 \cdot 1/30)$ compared with the value of 0.014 $(1/2 \cdot 1/35)$ with a single bucket. The investment share in the project types in the second subbucket has a higher value of 0.067 $(1/3 \cdot 1/5)$ compared with the value of 0.014 $(1/2 \cdot 1/35)$ with a single bucket.

The expected return and the expected risk (that is, expected standard deviation) of the portfolio of a naïvely diversifying decision maker are $\bar{\mu}^n = N\sum_{p \in \mathcal{P}} s^n(p)\mu(p)$ and $\bar{\sigma}^n = \sqrt{N\sum_{p \in \mathcal{P}} s^n(p)\sigma^2(p)}$, respectively. Thus, if subjects invest a greater share in projects with high levels of expected return and expected risk because of a higher threshold level between two buckets, the portfolio's expected return and expected risk increase. We formulate the following corollary.

Corollary 1. *The higher the threshold level p_b, the higher the portfolio's expected risk and return are.*

3.4. Behavioral Hypotheses

Naïve diversification results in project portfolios that are affected by the specification of buckets. If decision makers are prone to naïve diversification to some extent, observed decisions are influenced by bucket specifications as suggested by our model. In the following, we propose hypotheses on human project selection behavior, which we will test in our experimental studies with different bucket specifications. Our first hypothesis based on Proposition 1 states the effect of threshold levels on project selection.

Hypothesis 1. *The higher the threshold between two buckets, the higher the investment is per project type of the riskier bucket.*

Based on Corollary 1, we can also formulate expectations on the effect of threshold levels on portfolio's expected return and expected risk. The higher the threshold between two buckets, the higher the expected return and the expected risk of the resulting portfolio are.

According to Proposition 2, dividing a bucket into two buckets leads to a higher average investment in project types of this bucket, and we hypothesize the following.

Hypothesis 2. *If a subset of project types is assigned to two buckets instead of to one bucket, where the two buckets have the fractions f_{b_i} of the single bucket, then*

a. *the investment in those project types is higher and*

b. *the investment per project type of bucket b_i is higher (lower) if f_{b_i} is smaller (larger) than $|\mathcal{B}|/(|\mathcal{B}|+1)$.*

Our hypotheses were formulated to state how human behavior is affected by naïve diversification. In the following, we perform two behavioral studies to test the hypotheses. Our main study (Section 4) employs a student sample, presents projects sequentially, and characterizes project risk by uncertainty of payout. Our second study serves as a robustness check (Section 5) employing an Amazon Mechanical Turk (MTurk) sample, presenting projects simultaneously, and characterizing project risk as probability of success.

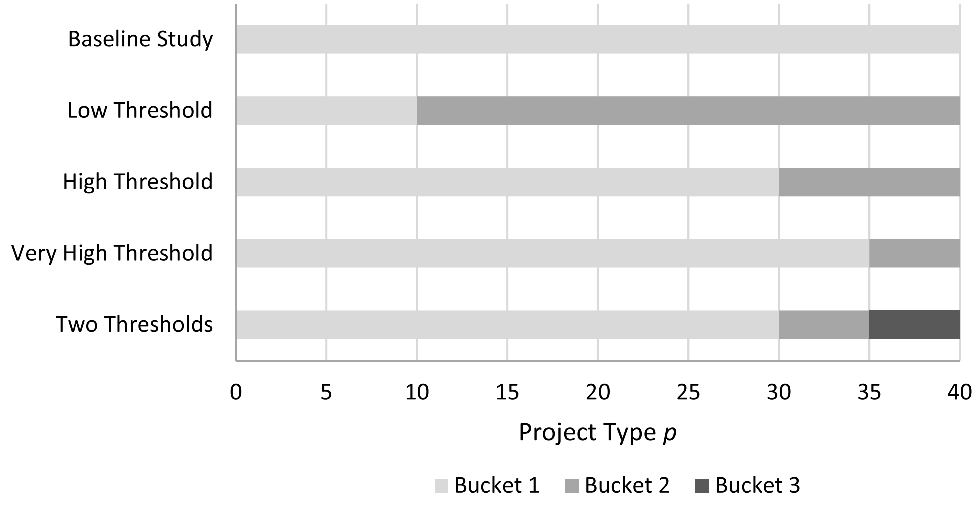
4. Main Study

We address our research question of whether and how the specification of strategic buckets influences project selection by an experimental study. This section contains the description of the experimental design, the experimental protocol, the main results, and an analysis of naïve diversification between and within buckets.

4.1. Experimental Design

We developed an experimental design that allows us to analyze how people allocate budget to project types. To test the effects of bucket specification on project selection, we vary the assignment of 40 project types to buckets between different experimental treatments in a between-subject design. In addition to a baseline treatment with a single bucket, we set up four treatments with different thresholds as illustrated in Figure 2. Three treatments have two buckets (that is, one threshold), and one treatment has three buckets (that is, two thresholds). We applied a low ($p_1 = 10$) threshold value, a high ($p_1 = 30$) threshold value, and a very high ($p_1 = 35$) threshold value for treatments

Figure 2. Treatments Main Study



with two buckets and a high ($p_1 = 30$) threshold value and a very high ($p_2 = 35$) threshold value for the treatment with three buckets. Our treatments allow us to analyze the effect of threshold levels and of the number of buckets on project selection.

In all treatments, we offer people projects from a set of 40 project types with different risk-return profiles and analyze how they allocate their budget of 10 projects. The realized project value is uncertain and follows a uniform distribution with an upper limit and a lower strictly positive limit. Projects with a higher spread of possible values combine higher risk levels with higher expected payout. Thus, there is no trivial dominance between project types; depending on risk preferences, decision makers may prefer different project types. The value range of projects of the least risky project type is between 9.775 and 10.375 (spread of 0.6), and the value range of the most risky project type is between 1 and 25 (spread of 24.0). With costs of 10, the expected profit ranges from 0.075 (standard deviation: 0.17) to 3 (standard deviation: 6.9). As there is no limit of possible projects, all possible portfolios can be selected independently of the bucket specification.

Rational but risk-sensitive decision makers would allocate all of the budget to a single project type or a combination of two adjacent project types (for example, project types 10 and 11) to obtain an efficient project portfolio: that is, a project portfolio that has the highest expected profit for a given expected risk level. Rational risk-neutral or risk-seeking decision makers select projects with the highest spread only.

In the experiment, the decision process starts with an *information phase*. In the bucket treatments, buckets are defined, and participants set bucket budgets in the *bucket phase*. Afterward, subjects select the projects in the *selection phase*. The experiment ends with a *postselection phase*. Treatments only differ in the bucket phase, where the numbers of buckets and thresholds between buckets are communicated and bucket budgets are set. This phase only exists in the treatments with multiple buckets, whereas it is skipped in the baseline treatment.

Information Phase. Subjects are informed that their task is to select 10 projects with equal costs from an infinite number of possible projects. They are informed that projects will be presented in a sequential order and that new projects will be presented until 10 projects in total have been selected. With 10 selected projects, the budget is exhausted. Subjects have all of the information required to determine the preferred project portfolio before starting the selection.

Bucket Phase. Subjects are informed that different buckets of project types exist. Buckets are defined by the threshold levels between them: for example, "projects where the spread of possible values is smaller than *-threshold-*" and "projects where the spread of possible values is greater than *-threshold-*." Subjects then decide on the number of projects that they want to select for each bucket: that is, bucket budgets. Their decision is binding and cannot be changed later.

Selection Phase. In the project selection phase, projects are presented in randomized order. Each project is characterized by the lower and upper limits of possible values. Each project can be either selected or dismissed. This step is repeated until 10 projects are selected. Subjects may build any portfolio as enough projects of each project type are presented.

Postselection Phase. After selecting the required number of projects, we elicit subjects' risk preference using the survey question validated in Dohmen et al. (2011) and collect demographics. Afterward, the selected projects' values are realized following a random draw from the respective distributions. Finally, subjects are informed about the outcomes of the 10 selected projects and their compensation.

4.2. Experimental Protocol

We relied on student subjects for our experiment (Donohue et al. 2018). A power analysis for our first hypothesis led to an aspired sample size of 60 subjects per treatment (linear regression, three threshold treatments leading to two independent variables, power 0.95, alpha 0.05, and moderate effect size f^2 0.1). A total of 313 subjects participated in the experiment, with between 62 and 64 subjects per treatment. All subjects were students recruited from the common subject pool of the University of Cologne. The experiment was programmed and conducted with the software z-Tree (Fischbacher 2007). The monetary unit applied was the experimental currency unit. Upon entering the laboratory, subjects were randomly assigned to a computer terminal and asked to read the instructions. During the experiment, communication between subjects was prohibited, and none was observed. There was no time pressure, and sessions took on average about 45 minutes. After information about the experiment was provided, all subjects had to pass a quiz to ensure a common understanding of the task. Only after answering all questions correctly, subjects could proceed with the experiment. Finally, subjects answered demographic questions. Upon completion of the session, each subject was privately paid their total earnings in cash. The average performance-dependent compensation was 9.90 euro.

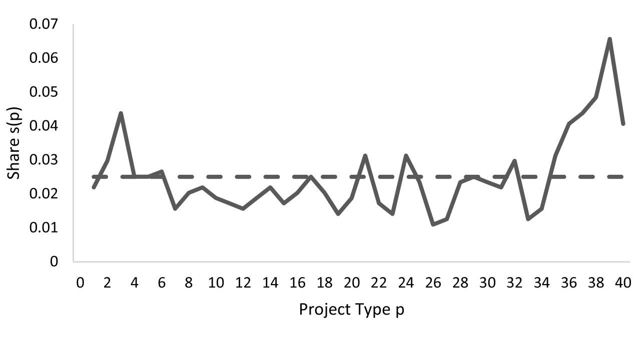
4.3. Study Results

Project Selection Without Strategic Buckets (Baseline Treatment). We illustrate the average invested budget share per project type in Figure 3. The average shares fluctuate around the mean share, having a peak at the more risky project types, which indicates a preference for the more risky, higher-expected-return project types. The dashed line in Figure 3 illustrates the naïve prediction: that is, the expected budget share of a naïvely diversifying decision maker for each project type.

On the individual level, all subjects chose more than one project type when selecting their 10 projects (average: 8.0, standard deviation: 1.6 different project types). Figure 4 visualizes the portfolios, where $s(p)$ denotes the share the subjects invested in project type p. Each subgraph in Figure 4 illustrates the portfolio of a subject. In Figure 4, the horizontal axis refers to the project types sorted by risk level from low (left) to high (right), and the vertical axis indicates the share invested per project type. Few subjects selected portfolios that could be matched to specific risk profiles. Subjects 30, 51, and 64 could be matched to risky profiles, and subject 14 could be matched to a rather conservative risk profile. Some subjects combine safe and risky projects, such as subjects 19, 49, and 50. However, most subjects spread their projects among many options. On average, expected profits of observed portfolios in the baseline treatment without buckets were 10.3% below those of "rational" portfolios: that is, portfolios with the same standard deviation composed of a single project type or a combination of two adjacent project types. We conclude that decision makers diversify among project types even if this conflicts with utility maximization based on risk and return.

Project Selection with Strategic Buckets. We summarize the theoretical prediction assuming full naïve diversification for all treatments combined with the observed results of our experimental study in Table 1, including the expected budget share per project type allocated to a bucket $\bar{s}(p)$, the expected value (EV), and the expected SD of portfolio profits.

Figure 3. Average Share of Invested Budget per Project Type Without Buckets

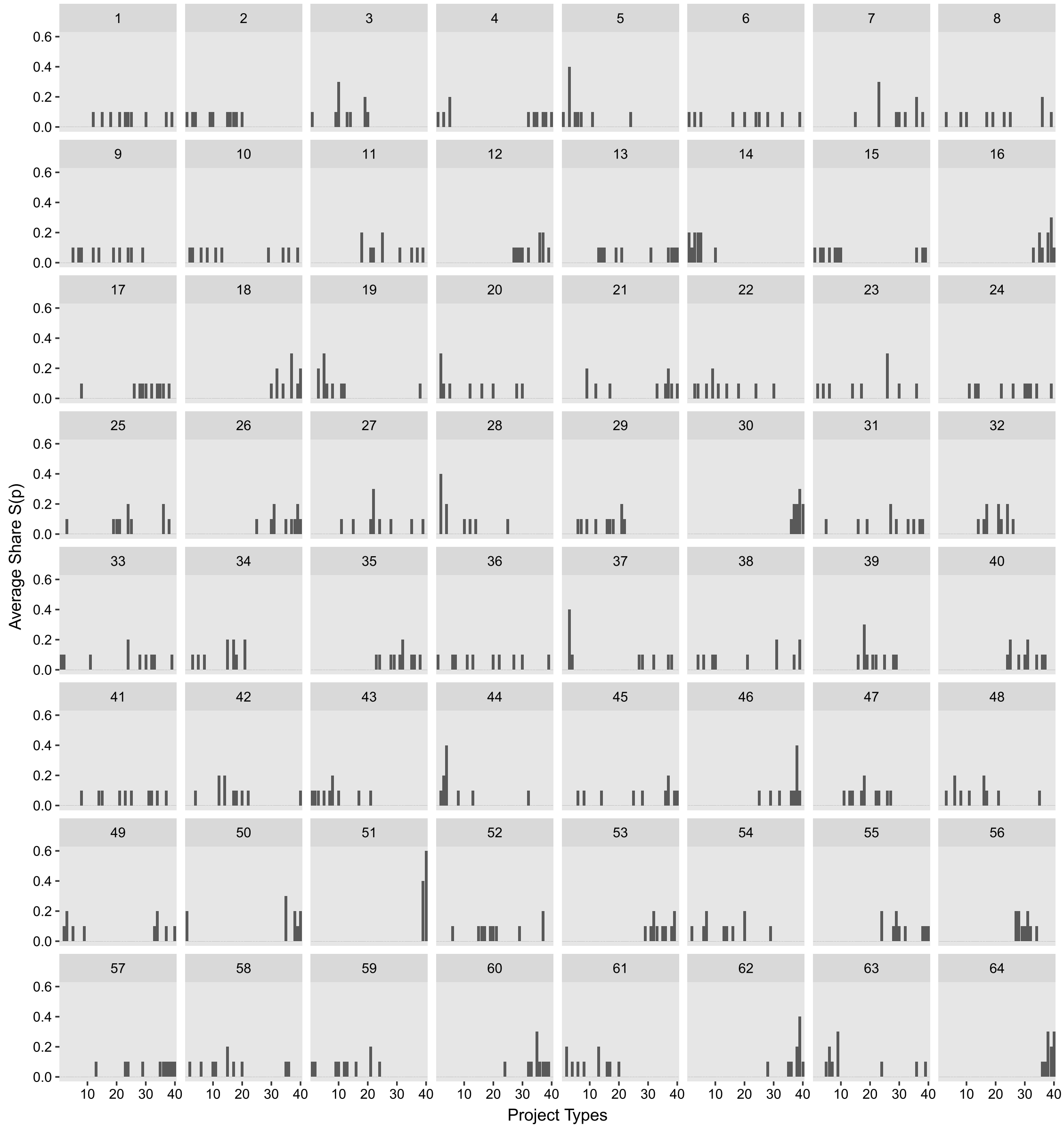


To analyze the effects of different thresholds between two buckets on project selection and resulting portfolios, we compare the results of the three treatments with two strategic buckets. The experimental results are illustrated in Figure 5, (a)–(c). The dashed lines in Figure 5 represent the average share invested in the project types of a bucket. The average share invested in projects of bucket 2 increases from 0.020 in the low-threshold treatment ($p_1 = 10$) to 0.060 in the high-threshold treatment ($p_1 = 30$) and to 0.119 in the very-high-threshold treatment ($p_1 = 35$). Table 1 shows that the expected return (EV) increases from 14.40 in the low-threshold treatment to 20.30 in the high-threshold treatment and to 21.88 in the very-high-threshold treatment. The expected portfolio risk (SD) increases accordingly. All treatment differences are in line with predictions from naïve diversification as shown in Table 1. A more detailed discussion on the predictive power of our model for the expected profit is provided in Online Appendix EC.2.

To test Hypothesis 1, we perform ordinary least squares (OLS) regression (observations on the subject level) (all regression equations are presented in Online Appendix EC.3). We use the low-threshold treatment as the base case and assign dummy variables to estimate the differences between the low- and high-threshold treatments and between the high- and very-high-threshold treatments. Table 2 provides the results. All parameter estimates for the treatment differences are positive and significant, which supports Hypothesis 1.

Hypothesis 2(a) states that assigning project types to two buckets instead of to one bucket leads to a higher investment share in those project types. We test Hypothesis 2(a) using OLS regression (observations on the subject level) with a dummy variable for having two buckets instead of one. The regression results are summarized in the second column in Table 3. Our first comparison (the upper panel of Table 3) compares bucket 2 of the high-threshold treatment (project types 31–40) with bucket 2 (project types 31–35) and bucket 3 (project types 36–40) of the two-thresholds treatment. Our second comparison (the lower panel of Table 3) compares bucket 1 (project types 1–35) of the very-high-threshold treatment with bucket 1 (project types 1–30) and bucket 2 (project types 31–35) of the two-thresholds treatment. For our first comparison, investment shares of project types 31–40 show a higher average share of 0.073 in the two-thresholds treatment compared with 0.060 in the high-threshold treatment ($p < 0.01$). For our second comparison, assigning project types 1–35 to two buckets instead of to one bucket leads to a higher average share per project type of 0.018 versus 0.012 ($p < 0.01$). Thus, we find support for our Hypothesis 2(a) in both comparisons as creating two buckets instead of one

Figure 4. Invested Share per Project Type $s(p)$ by Subject Without Buckets



bucket led to higher investments in the affected project types in total.

Hypothesis 2(b) states the expected effects on project types assigned to each of the two subbuckets. In analogy to testing Hypothesis 2(a), we test both comparisons for both subbuckets using OLS regression models (observations on the subject level) with a dummy variable for having two buckets instead of one. The regression results are summarized in the third and fourth columns in Table 3 for the first and second subbucket, respectively. For our first comparison, buckets 2 and 3 of the two-thresholds treatment have a fraction of 0.5 of the project types 31–40, which is below the value of $|\mathcal{B}|/(|\mathcal{B}|+1)=2/3$. Thus, the expected investment share for project types of both subbuckets is expected to be higher than for the case of a single bucket 2 in the high-threshold treatment. The average invested share in the two-thresholds treatment is higher than in the high-threshold treatment for project types 31–35 (0.067 versus 0.060, $p=0.331$) and for project types 36–40 (0.079 versus 0.059, $p=0.019$). For our second comparison, the fractions of buckets 1 and 2 of the two-thresholds treatment are 6/7 and 1/7 of the project types 1–35, respectively. As the fraction of bucket 1 exceeds the value of $|\mathcal{B}|/(|\mathcal{B}|+1)=2/3$, we expect investment shares of project types of this bucket to be below the case of the very-high-threshold treatment. As the fraction of bucket 2 of 1/7 is below the value of 2/3, we expect investment shares in the project types assigned to it to be higher compared with the case of the very-high-threshold treatment. As stated in

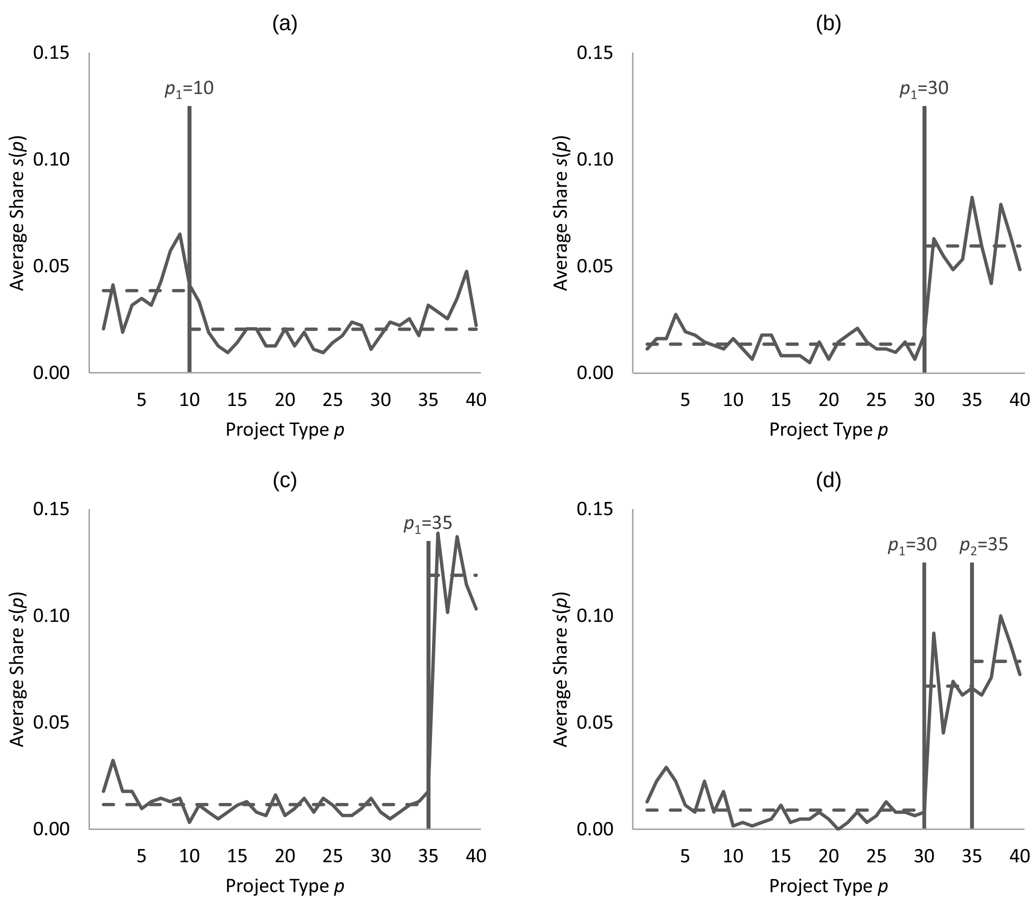
Table 1. Summary Predicted and Observed Portfolios

Treatment	Thresholds	$\bar{s}(p)$ $p \in \mathcal{P}_1$	$p \in \mathcal{P}_2$	$p \in \mathcal{P}_3$	EV	SD
Naïve predictions						
Baseline study	None	0.025			15.40	12.89
Low threshold	10	0.050	0.017		11.68	10.70
High threshold	30	0.017	0.050		19.13	15.41
Very high threshold	35	0.014	0.100		21.01	16.76
Two thresholds	30, 35	0.011	0.067	0.067	21.62	16.89
Observations						
Baseline study	None	0.025			16.78	13.33
Low threshold	10	0.039	0.020		14.40	12.10
High threshold	30	0.013	0.060		20.30	16.02
Very high threshold	35	0.012	0.119		21.88	17.24
Two thresholds	30, 35	0.009	0.067	0.079	21.96	17.17

Note. EV, expected value; SD, standard deviation.

Hypothesis 2(b), the average invested share per project type is lower in the two-bucket case for project types 1–30 (0.009 versus 0.012, $p = 0.033$) and higher for project types 31–35 (0.067 versus 0.011, $p < 0.01$). Thus, we find support for Hypothesis 2(b) in all cases, except for the directional but nonsignificant difference of invested share in projects 31–35 when comparing the high-threshold treatment with the two-thresholds treatment. Investment in project types assigned to a subbucket (instead of a larger bucket) increases or decreases according to the threshold of the subbucket and the total number of buckets. Figure 5 illustrates the share invested in each project type for those treatments.

Figure 5. Effect of Thresholds on Invested Share



Notes. (a) Low threshold. (b) High threshold. (c) Very high threshold. (d) Two thresholds.

Table 2. Regression Results: Effect of Bucket Threshold

	$\bar{s}(p),\, p \in \mathcal{P}_2$	EV	SD
Constant (low threshold)	0.020***	14.404***	12.104***
ΔLow to high threshold	0.040***	5.896***	3.914***
ΔHigh to very high threshold	0.060***	1.581*	1.218**
Observations	187	187	187
Adjusted R^2	0.648	0.311	0.357

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

4.4. Naïve Diversification Between and Within Buckets

In the following, we quantify to which degree decision makers are prone to naïve diversification between and within buckets. To quantify naïve diversification, we develop a behavioral model first before estimating the degree of naïve diversification based on our experimental data.

Behavioral Model. A risk-sensitive decision maker invests share $s^r(p)$ and a naïvely diversifying decision maker invests share $s^n(p)$ in project type p. A human decision maker might exhibit behavior of both types. We model the behavior of such individuals by specifying the weight that a person places on naïve diversification (α) and the weight that they place on the risk-sensitive solution $(1-\alpha)$.

Naïve diversification may influence decision makers when dividing the total project budget among buckets but also, when investing the bucket budget among the project types within the bucket. We model this as a two-step decision process. First, the assignment of budget to buckets is determined; second, the expected share invested in each project type is determined. We denote the weight that a person places on naïve diversification when allocating the budget between buckets by α^β and the weight that they place on naïve diversification when allocating the bucket budgets among the project types within a bucket by α^ω.

To model the degree of naïve diversification between buckets, we express the expected budget share $\widehat{s^\beta}(b)$ in all project types associated with bucket b as a weighted sum of the expected share invested in bucket b by a naïvely diversifying decision maker $(1/|\mathcal{B}|)$ and of the expected share invested in bucket b by a risk-sensitive decision maker ($s^r(b) = \sum_{p\in\mathcal{P}_{b(p)}} s^r(p)$):

$$\widehat{s^\beta}(b) = \sum_{p\in\mathcal{P}_{b(p)}} s(p) = \alpha^\beta \frac{1}{|\mathcal{B}|} + (1-\alpha^\beta)s^r(b). \tag{4}$$

To model the degree of naïve diversification *within* a bucket b with given investment level s_b, we express the expected budget share $\widehat{s^\omega_b}(p)$ of bucket b invested in project type p as a weighted sum of the expected share invested by a naïvely diversifying decision maker $(1/|\mathcal{P}_{b(p)}|)$ and of the expected share invested by a risk-sensitive decision maker ($s^r_b(p)$):

$$\widehat{s^\omega_b}(p) = \alpha^\omega \frac{1}{|\mathcal{P}_{b(p)}|} + (1-\alpha^\omega)s^r_b(p). \tag{5}$$

Parameter Estimation. To estimate the degree of naïve diversification between (α^β) and within (α^ω) buckets, we use maximum likelihood estimation. Let $b=1$ be the bucket with the highest number of assigned projects and $p=1$ be the project type with the highest number of assigned projects within any bucket. In case of ties, the bucket or project type with the lower index is selected (note that in this case, the choice does not affect the result). We assume that this bucket and project types represent the rational choice considering risk preferences. Thus, the observed budget share allocated to the budget with the highest number of assigned projects is $s^\beta(1)$, and the observed budget share allocated to the project type with the highest number of assigned projects is $s^\omega_b(1)$. The maximum likelihood estimators for α^β and α^ω are as follows (proofs are contained in Online Appendix EC.1):

$$\alpha^\beta = \frac{N(1-s^\beta(1))}{N}\cdot\frac{|\mathcal{B}|}{|\mathcal{B}|-1}, \tag{6}$$

$$\alpha^\omega = \frac{N(1-s^\omega_b(1))}{N}\cdot\frac{|\mathcal{P}_{b(p)}|}{|\mathcal{P}_{b(p)}|-1}. \tag{7}$$

We report the average values of the estimated naïve diversification parameters for all treatments in Table 4.

Table 3. Regression Results: Effect of Additional Bucket

	$\bar{s}(p),\, p \in \{31–40\}$	$\bar{s}(p),\, p \in \{31–35\}$	$\bar{s}(p),\, p \in \{36–40\}$
Constant (high threshold)	0.060***	0.060***	0.059***
ΔSplit bucket $\mathcal{P}_2$	0.013***	0.007	0.020**
Observations	124	124	124
Adjusted R^2	0.104	0.000	0.036
	$\bar{s}(p),\, p \in \{1–35\}$	$\bar{s}(p),\, p \in \{1–30\}$	$\bar{s}(p),\, p \in \{31–35\}$
Constant (very high threshold)	0.012***	0.012***	0.011***
ΔSplit bucket $\mathcal{P}_1$	0.006***	−0.003**	0.056***
Observations	124	124	124
Adjusted R^2	0.144	0.029	0.462

**$p < 0.05$; ***$p < 0.01$.

Table 4. Summary Naïve Diversification over Treatments

Treatment	Threshold	Between buckets (α^{β})	Within buckets (α^{ω})
Baseline study	None	—	0.792
Low threshold	10	0.657	0.715
High threshold	30	0.648	0.736
Very high threshold	35	0.616	0.709
Two thresholds	30, 35	0.658	0.635

The naïve diversification between buckets parameters, α^{β}, ranges between values of 0.616 and 0.658. Regarding the naïve diversification within buckets parameters, α^{ω}, we differentiate between cases with different average bucket size: In case of our baseline study, we observe an average value of 0.792. For the three treatments with one threshold, we observe average values of 0.715, 0.736, and 0.709. The treatment with two thresholds has an average value of 0.635. In summary, we observe consistent parameters for naïve diversification between buckets over all treatments and consistent parameters for naïve diversification within buckets over all treatments with the same number of buckets.

4.5. Replication of the Main Study with Lenient Bucket Implementation

We replicated our main results with lenient implementations of strategic buckets (see Online Appendix EC.4), where bucket budgets could be adjusted during project selection ("adjustable buckets") and where project types are only classified into buckets without specifying explicit bucket budgets ("classification"). Those treatments differ from the buckets treatments of the main study. In the adjustable buckets treatments, subjects are informed in the bucket phase that their decision on bucket budgets is not binding and can be changed later. In the following selection phase, they can reallocate their bucket budgets any time. In the classification treatments, participants are merely informed that there are different project types in the bucket phase, and no bucket budgets are set. The treatment differences are consistent with the previous ones and support our hypotheses. The parameters for diversification between buckets were on average but not significantly smaller for adjustable buckets (low threshold: 0.644, t-test $p = 0.81$, high threshold: 0.571, t-test $p = 0.15$) and significantly smaller for classification treatments (low threshold: 0.445, high threshold: 0.410, t-test $p < 0.01$ in both cases). Thus, we observe that the diversification effect already exists for pure classification, becomes stronger with adjustable buckets, and is strongest with binding buckets. The parameters for diversification within buckets were in line with our main study (values lie in the range between 0.720 and 0.745). For more detailed results, we refer to Online Appendix EC.4.

5. Robustness Study

The main finding of our experimental study is that project selection is affected by strategic buckets. We found support for Hypothesis 1 that setting the threshold between two buckets toward more risky project types leads to higher average investment in project types of the high-risk bucket. To analyze robustness of this key result, we run an additional robustness study.

Analytical research on project portfolio optimization typically distinguishes between multistage approaches (like dynamic programming), where information becomes known sequentially, and single-stage approaches (like knapsack problems), where all information is known simultaneously (Si et al. 2022). One critical assumption that we made in the main study is that projects were presented and selected sequentially. Although being realistic in some settings, companies could also collect potential projects before making portfolio decisions (Schiffels et al. 2018). Thus, we present projects simultaneously in the robustness study. Another assumption was that risk is presented by the spread between the minimum and maximum values of projects. Especially risky projects might have an all-or-none logic that would increase salience of risk to decision makers. Thus, we defined risk as probability of success in the robustness study. Furthermore, to analyze the robustness with respect to the subject pool (our first behavioral study was based on a student sample), we use the online Amazon MTurk subject pool in the robustness study.

5.1. Experimental Design

Similarly to the behavioral study in the previous section, we analyze how subjects allocate their budget to projects depending on the specification of buckets: in this case, the threshold between two buckets. Thus, our experimental treatments differ between the assignment of four generic project types to buckets. In addition to a baseline treatment without strategic buckets, we consider two treatments with two strategic buckets and different bucket thresholds. In all treatments, the budget is set such that subjects can select six projects (all projects have equal costs of investment). In the baseline treatment 1 (no buckets), we present six projects of each type. Treatment 2 (low threshold) includes two buckets; one bucket is associated with 18 projects of the least risky type 1, and one bucket is associated with 6 projects of each of the three most risky types

(types 2–4). Treatment 3 (high threshold) includes one bucket associated with 6 projects of each of the three least risky types (types 1–3) and one bucket associated with 18 projects of the most risky type 4. This way, we ensure that subjects can select their entire budget of six projects from each type.

The value of each project is only realized if the project was successful; otherwise, the project does not return any value. We distinguish between four generic project types (type 1 with values of 106–116 and probability of success of 96.0%–90.1%, type 2 with values of 212–242 and probability of success of 59.1%–53.9%, type 3 with values of 424–464 and probability of success of 36.4%–34.2%, and type 4 with values of 848–958 and probability of success of 22.4%–20.6%). Projects with higher values are associated with lower probabilities of success, and no trivial dominance between projects exists. As in the previous studies, rational decision makers who are risk neutral or risk seeking would only select projects of the highest risk type (type 4). The least risky project has a value of 106 and a probability of success of 96.0%, whereas the most risky project has a value of 958 and a probability of success of 20.6%. The expected profit (given equal investment costs of 100 per project) ranges from 5.8 with a standard deviation of 1.2 to 176.8 with a standard deviation of 374.0. Thus, we consider a great difference between the risk-return profiles of the project types.

As in the previous set of experiments, the decision process starts with an *information phase* followed by a *bucket phase* and a *selection phase*, and it ends with a *postselection phase*. As in the previous study, only the bucket phase differs between treatments. It exists only in the two-buckets treatments, whereas it is skipped in the baseline treatment.

Information Phase. Subjects are informed that their task is to select six projects with equal investment costs. Each project is characterized by a value and a probability of success. The value is only realized if the project was successful; otherwise, the project has zero return. Subjects are also informed about the mechanism to determine project success. For each project, a random number between 1 and 100 is drawn to determine the success. If the number was smaller than or equal to the probability of success, the project was successful. Otherwise, the project failed.

Bucket Phase. Subjects are informed that there are different buckets of project types. Classes of project types are defined by threshold levels of value and probability of success. Thus, all projects with a value smaller than the threshold and a probability of success greater than the threshold are associated with one bucket, whereas all projects with a value greater than the threshold and a probability of success smaller than the threshold are associated with the other bucket. Afterward, subjects decide on the number of projects that they want to select for each bucket (that is, bucket budgets). They are informed that the bucket budgets can be changed later.

Selection Phase. In the project selection phase, we represent all projects simultaneously on a screen in random order. In all treatments, all projects are displayed on the same page. Each project is characterized by the value and probability of success. In total, six projects have to be selected. In treatments with bucket budgets, the allocated number of projects has to be selected for each bucket. Subjects could return to the bucket phase if they want to change the bucket allocation.

Postselection Phase. After selecting the required number of projects, we elicit subjects' risk preference using the survey question validated in Dohmen et al. (2011) and collect demographics. Afterward, the selected projects' successes are realized following randomly drawn numbers. Finally, subjects are informed about the outcomes of the selected projects and receive their compensation.

5.2. Experimental Protocol

To test a different subject pool, we relied on subjects of the online platform Amazon MTurk using the Cloud Research subject pool (Douglas et al. 2023). A power analysis for our first hypothesis led to an aspired sample size of 200 per treatment (linear regression, two-threshold treatments leading to one independent variable, power 0.95, alpha 0.05, small effect size f^2 0.033; we consider one third of the expected effect size compared with the main study because of the online experiment setting). A total of 600 subjects participated in the experiment, between 199 and 201 per treatment. All subjects were recruited using the CloudResearch platform for Amazon MTurk with approved participants only. The experiment was programmed and conducted with the software Qualtrics. After finishing the information phase, all subjects had to pass a quiz to ensure a common understanding of the task. Only after answering all questions correctly, subjects could proceed to the selection phase. Subjects who failed the quiz were excluded from the study. After passing the quiz, subjects were randomly assigned to the three treatments. After finishing the project selection task, subjects answered demographic questions. Within a day of the experiment, each subject was paid their total earnings. The average performance-dependent compensation was $1.82 for an average duration of 6.8 minutes. Eleven subjects only selected five projects instead of six, and we excluded them from the analysis. Including them does not change any main findings.

Table 5. Summary Results Robustness Check

	$\bar{s}(p)$			
Treatment	$p \in \mathcal{P}_1$	$p \in \mathcal{P}_2$	EV	SD
Naïve predictions				
Baseline			871.4	542.0
Low threshold	0.500	0.167	787.2	444.4
High threshold	0.167	0.500	967.8	686.0
Observations				
Baseline			856.0	475.0
Low threshold	0.488	0.171	804.0	422.1
High threshold	0.218	0.347	889.4	543.9

5.3. Results

Across all treatments, most subjects (73%) selected projects belonging to at least two of four different project types. On average, subjects selected projects of 2.2 different types. Table 5 shows that compared with the baseline treatment without buckets, the low-threshold treatment leads to lower expected return and lower average standard deviation, whereas the high-threshold treatment leads to higher expected return and higher average standard deviation of project portfolios.

To validate our main finding that higher thresholds between two buckets lead to higher average investment in project types of the high-risk bucket (Hypothesis 1) and that this results in an increased expected return and risk of the resulting portfolios, we perform OLS regression models (observations on the subject level). We use the low-threshold treatment as the base case and assign dummy variables to estimate the difference between the low- and high-threshold treatments, and we summarize the results in Table 6. We see significant parameter estimates for the treatment differences on project selection as well as on portfolio expected value and standard deviation.

We also estimate the naïve diversification parameters α^{β} for diversification between buckets. The average values of diversification between buckets α^{β} range between 0.517 (high threshold) and 0.591 (low threshold). These values are similar to the corresponding "adjustable buckets" variant of our main study, where α^{β} ranges between 0.571 and 0.644 (see Online Appendix EC.4). Please note that the robustness experiment is not suitable to analyze diversification within buckets as the smaller bucket only consists of one project type.

Table 6. Regression Results Robustness Study: Effect of Bucket Threshold

	$\overline{S}(p), p \in \mathcal{P}_2$	EV	SD
Constant (low threshold)	0.171***	804.01***	422.08***
ΔLow to high threshold	0.176***	85.35***	121.85***
Observations	389	389	389
Adjusted R^2	0.154	0.069	0.057

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

In summary, our robustness checks indicate that our main findings can be replicated with a different selection process (simultaneous selection versus sequential decision on project proposals), a different project definition (success or fail versus spread of value), and a different subject pool (American MTurk workers versus students). Overall, our robustness study validates our main findings for variations of the experimental setting, thereby also increasing the external validity.

6. Conclusions

To align a company's project portfolio with its objectives, companies can specify guidelines on project selection and leave actual project selection to managers. However, if managers are prone to decision biases, the company's project portfolio might not optimally contribute to the company's objectives. An approach to better align managers' project selection with corporate objectives is the use of strategic buckets. Classifying projects and applying buckets for certain types of projects are common practices, and related concepts are widely discussed both in the academic literature and the managerial literature (Cooper et al. 2004, Chao and Kavadias 2008, Hutchison-Krupat and Kavadias 2015). We propose a model that relies on naïve diversification and predicts the effect of strategic bucket specification, such as the number of buckets or thresholds between buckets, on project selection behavior. Based on the model, we derive hypotheses on the effect of bucket specification on project selection behavior. Running our main experimental study with a student sample, we found support for our hypotheses; thresholds between buckets and the number of buckets affect project selection. The experimental results indicate that people have the tendency to allocate budgets evenly among strategic buckets and evenly among the project types within strategic buckets. Thus, people are prone to a naïve diversification bias during project selection. Although the main study represents a setup that is common in reality—new project ideas are continuously evaluated once they are created—different setups exist. Thus, we replicated the main results in a robustness study, where new project ideas are evaluated once all ideas are collected. Furthermore, the robustness study differed in terms of project risk (probability of success instead of spread between minimum and maximum values) and subject pool (Amazon MTurk subject pool instead of student sample).

Our results have important managerial implications. Strategic buckets are a popular approach to steer project portfolios. However, managers should be aware that strategic buckets can trigger decision biases. As soon as projects are classified, people have the tendency to spread budgets evenly among project classes and evenly among the project types within the classes. Thus, managers setting bucket budgets might be prone to naïve diversification. The naïve diversification bias can also be considered by executives to nudge project portfolio managers to select projects such that the resulting portfolios are aligned with corporate strategy without having to enforce inflexible rules that limit the project portfolio manager's discretion. For example, if the company is seeking to increase the share of innovative projects, executives might want to define several innovation buckets instead of having one common bucket for all innovation projects.

Our study uses a highly stylized setting focusing on isolating the effect of naïve diversification in different bucket regimes, which comes with some limitations. First, our study only considers risk and return as project attributes. The naïve diversification bias could also hold when projects are classified by different characteristics, such as geographic location, product type, or time horizon. It would be interesting to explore such approaches in future research. Second, another potential area of future research would be embedding the effect of naïve diversification in more complex decision models. Although assuming that each project has a homogeneous budget of one enabled clear hypotheses and intuitive analyses, it might be worthwhile to consider projects with heterogeneous budgets, allowing for differentiation between naïve diversification of the number of projects and naïve diversification of project budgets. Third, we assume that naïve diversification over buckets is not influenced by bucket specification. This may change if buckets obviously differ: for example, in the number of available projects, economic size, or strategical importance.

Although recent behavioral studies shed light on different aspects of project management, such as on the initiation of new product development projects (Wuttke et al. 2018), the transition from project ideation to execution (Kagan et al. 2018), agile project management (Lieberum et al. 2022), or the abandonment of projects (Long et al. 2020), we contribute to the behavioral understanding of project selection, an area where there is much yet to be discovered.

References

Bardolet D, Fox CR, Lovallo D (2011) Corporate capital allocation: A behavioral perspective. *Strategic Management J.* 32(13): 1465–1483.

Benartzi S, Thaler RH (2001) Naive diversification strategies in defined contribution saving plans. *Amer. Econom. Rev.* 91(1):79–98.

Bird R, Tippett M (1986) Naive diversification and portfolio risk—A note. *Management Sci.* 32(2):244–251.

Chandrasekaran A, Linderman K, Schroeder R (2015) The role of project and organizational context in managing high-tech R&D projects. *Production Oper. Management* 24(4):560–586.

Chao RO, Kavadias S (2008) A theoretical framework for managing the new product development portfolio: When and how to use strategic buckets. *Management Sci.* 54(5):907–921.

Cohn RA, Lewellen WG, Lease RC, Schlarbaum GG (1975) Individual investor risk aversion and investment portfolio composition. *J. Finance* 30(2):605–620.

Cooper RG (2006) Managing technology development projects. *Research-Tech. Management* 49(6):23–31.

Cooper RG, Edgett SJ, Kleinschmidt EJ (2004) Benchmarking best NPD practices—II. *Research-Tech. Management* 47(3):50–59.

Dohmen T, Falk A, Huffman D, Sunde U, Schupp J, Wagner GG (2011) Individual risk attitudes: Measurement, determinants, and behavioral consequences. *J. Eur. Econom. Assoc.* 9(3):522–550.

Donohue K, Katok E, Leider S, eds. (2018) *The Handbook of Behavioral Operations* (Wiley, Hoboken, NJ).

Douglas BD, Ewell PJ, Brauer M (2023) Data quality in online human-subjects research: Comparisons between MTurk, Prolific, CloudResearch, Qualtrics, and SONA. *PLoS One* 18(3):e0279720.

Dow J, da Costa Werlang SR (1992) Uncertainty aversion, risk aversion, and the optimal choice of portfolio. *Econometrica* 60(1):197–204.

Fischbacher U (2007) z-tree: Zurich toolbox for ready-made economic experiments. *Experiment. Econom.* 10(2):171–178.

Fox CR, Ratner RK, Lieb DS (2005) How subjective grouping of options influences choice and allocation: Diversification bias and the phenomenon of partition dependence. *J. Experiment. Psych. General* 134(4):538–551.

Gurnani H, Ramachandran K, Ray S, Xia Y (2014) Ordering behavior under supply risk: An experimental investigation. *Manufacturing Service Oper. Management* 16(1):61–75.

Hutchison-Krupat J, Kavadias S (2015) Strategic resource allocation: Top-down, bottom-up, and the value of strategic buckets. *Management Sci.* 61(2):391–412.

Kagan E, Leider S, Lovejoy WS (2018) Ideation–execution transition in product development: An experimental analysis. *Management Sci.* 64(5):2238–2262.

Lieberum T, Schiffels S, Kolisch R (2022) Should we all work in sprints? How agile project management improves performance. *Manufacturing Service Oper. Management* 24(4):2293–2309.

Loch CH (2017) Creativity and risk taking aren't rational: Behavioral operations in MOT. *Production Oper. Management* 26(4):591–604.

Loch C, Kavadias S, eds. (2007) *Handbook of New Product Development Management* (Routledge, London).

Long X, Nasiry J, Wu Y (2020) A behavioral study on abandonment decisions in multistage projects. *Management Sci.* 66(5):1999–2016.

Markham SK, Lee H (2013) Product development and management association's 2012 comparative performance assessment study. *J. Product Innovation Management* 30(3):408–429.

McKinsey (2013) *Global Strategy Survey 2013* (McKinsey Publishing, New York).

Page AL (1993) Assessing new product development practices and performance: Establishing crucial norms. *J. Product Innovation Management* 10(4):273–290.

Rabin M, Thaler RH (2001) Anomalies: Risk aversion. *J. Econom. Perspect.* 15(1):219–232.

Read D, Loewenstein G (1995) Diversification bias: Explaining the discrepancy in variety seeking between combined and separated choices. *J. Experiment. Psych. Appl.* 1(1):34–49.

Read D, Loewenstein G, Kalyanaraman S (1999) Mixing virtue and vice: Combining the immediacy effect and the diversification heuristic. *J. Behav. Decision Making* 12(4):257–273.

Read D, Antonides G, Van den Ouden L, Trienekens H (2001) Which is better: Simultaneous or sequential choice? *Organ. Behav. Human Decision Processes* 84(1):54–70.

Schiffels S, Fliedner T, Kolisch R (2018) Human behavior in project portfolio selection: Insights from an experimental study. *Decision Sci.* 49(6):1061–1087.

Si H, Kavadias S, Loch C (2022) Managing innovation portfolios: From project selection to portfolio design. *Production Oper. Management* 31(12):4572–4588.

Simonson I (1990) The effect of purchase quantity and timing on variety-seeking behavior. *J. Marketing Res.* 27(2):150–162.

Simonson I, Winer RS (1992) The influence of purchase quantity and display format on consumer preference for variety. *J. Consumer Res.* 19(1):133–138.

Thaler RH (1999) Mental accounting matters. *J. Behav. Decision Making* 12(3):183–206.

Tu J, Zhou G (2011) Markowitz meets Talmud: A combination of sophisticated and naive diversification strategies. *J. Financial Econom.* 99(1):204–215.

Wuttke DA, Donohue K, Siemsen E (2018) Initiating supplier new product development projects: A behavioral investigation. *Production Oper. Management* 27(1):80–99.