Crowdsourcing Processes and Performance Outcomes

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CROWDSOURCING PROCESSES AND PERFORMANCE OUTCOMES

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Nathan Rietzler

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Department of Strategy and Innovation

PhD Series 19.2023

CBS COPENHAGEN BUSINESS SCHOOL
HANDELSHØJSKOLEN

Crowdsourcing Processes and Performance Outcomes

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For Mom.

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Summary

Crowdsourcing has become a prominent method for organizations to search for external knowledge as part of their innovation process. In doing so, organizations first set up an innovation contest in which they post a problem for participants to solve. Participants can then either work on a solution alone or cooperate with other participants. Subsequently, organizations evaluate the submitted solutions and attempt to turn the best of them into innovations. Much of the prior literature on crowdsourcing and innovation contests, however, treats competition and cooperation as two separate dimensions. Hence, we know little about how they interact, how this interaction plays out in terms of performance implications and under what conditions crowdsourcing participants would actually cooperate with their competitors. Further, prior literature offers conflicting evidence on the performance outcomes translating these crowdsourcing inputs into innovation performance on a firm level. This thesis addresses these issues in three chapters.

The first chapter explores how coopetition between individuals, that is, cooperating under competitive conditions, impacts idea quality in innovation contests. The chapter presents evidence from a laboratory experiment in which participants generated ideas to a real-world problem but did so under different cooperation and competition conditions. Compared to the no-cooperation condition, allowing for cooperation under competition does not yield an average effect on an idea's novelty. It does, however, have a positive effect on the user benefit and a negative effect on the feasibility of an idea. Focusing solely on the very best ideas confirms the average quality effects for user benefits and feasibility but also finds more ideas from the cooperation condition among the most novel ones.

The second chapter then investigates how and under what conditions competitive reward structures influence the likelihood of individuals to cooperate in innovation contests. The chapter conducts interviews and two experiments combined with an adaptive choice-based conjoint and cluster ensemble analysis. It finds that higher levels of competition significantly reduce an individual's likelihood to cooperate. This effect is driven by individuals' reduced likelihood to share knowledge with competitors rather than to absorb knowledge from them. Investigating the drivers of the cooperation likelihood results into two main clusters of interdependent factors: one cluster is dominated by individuals' fear of knowledge misappropriation by other contestants. Participants in this cluster would be (more) likely to cooperate if this fear is addressed (and ideally eliminated) by the innovation contest design. The other main cluster consists of multiple factors

that always includes either intrinsic or extrinsic motivation in conjunction with, for example, the prior helpfulness of other participants or the complexity of the problem to be solved.

The last chapter examines the how the use of crowdsourcing as an innovation method impacts firms' innovation performance and which conditions positively influence this relationship. Using firm-level innovation data from Germany, this chapter finds a positive relationship between the use of crowdsourcing as an innovation method and firms' innovation performance in most empirical models. Further, it presents evidence that this relationship is positively moderated by firms' digital capabilities.

The dissertation holds several theoretical and managerial implications. It extends prior research on coopetition and on crowdsourcing as a solution to distant search. Moreover, it provides guidance to managers who seek to engineer the quality of crowdsourced solutions and their organizations' ability to benefit from them.

Resumé

Crowdsourcing er blevet en prominent metode for organisationer til at søge ekstern viden som en del af deres innovationsproces. Når dette gøres, etablerer organisationerne først en innovationskonkurrence, hvor de offentliggør et problem som deltagerne kan løse. Deltagere kan enten arbejde på løsningen alene eller samarbejde med andre deltagere. Derefter evaluerer organisationerne de indsendte løsninger i et forsøg på at gøre de bedste af dem til innovationer. Tidligere litteratur inden for crowdsourcing og innovationskonkurrencer anser konkurrence og samarbejde som to separate dimensioner. Dermed ved vi ikke meget om hvordan de interagerer, hvordan denne interaktion udspiller sig i form af resultatimplikationer, og under hvilke omstændigheder crowdsourcing deltagere samarbejder med deres konkurrenter. Derudover har tidligere litteratur tilvejebragt modstridende evidens når det kommer til afgræsninger og præstationsresultater ved at adoptere og oversætte disse crowdsourcingsinputs på virksomhedsniveau. Denne afhandling adresserer disse problemstillinger i tre kapitler.

Det første kapitel udforsker hvordan samarbejde mellem individer under konkurrencemæssige forhold påvirker idékvaliteten i innovationskonkurrencer. Kapitlet præsenterer evidens fra et laboratorieeksperiment, hvor deltagerne har genereret løsningsidéer til en problemstilling fra den virkelige verden under forskellige samarbejds- og konkurrencebetingelser. Sammenlignet med betingelsen uden samarbejde giver samarbejde når der er konkurrence ingen gennemsnitlig effekt på nyhedsværdien af idéer. Det har dog en positive effekt på brugerfordele samt en negativ effekt på gennemførligheden af idéerne. Fokuseres der kun på de allerbedste idéer bekræftes den gennemsnitlige kvalitetseffekt for brugerfordele og gennemførlighed, men der vises også, at der er flere idéer fra konkurrencebetingelsen blandt de mest nytænkende idéer.

Kapitel 2 undersøger hvordan og under hvilke betingelser den konkurrencemæssige belønningsstruktur påvirker sandsynligheden for at individer samarbejder i innovationskonkurrencer. Kapitlet udfører interviews og to eksperimenter kombineret med en adaptive choice-based conjoint and cluster ensemble analyse. Disse analyser viser at højere niveauer af konkurrence signifikant reducerer et individs sandsynlighed for at samarbejde. Denne effekt er drevet af individets nedsatte tilbøjelighed til at dele viden med konkurrenter frem for at absorbere viden fra dem. En undersøgelse af drivkræfterne bag samarbejdstilbøjelighed resulterer i to hovedklynger af uafhængige faktorer: en klynge er domineret af individers frygt for uretmæssig tilegnelse af viden blandt andre deltagere. Deltagere i denne klynge har større

tilbøjelighed til at samarbejde hvis denne bekymring adresseres (og ideelt set elimineret) af innovationskonkurrencedesignet. Den anden hovedklynge består af forskellige faktorer som altid inkluderer iboende eller ekstern motivation i konjunktion med, for eksempel, den tidligere hjælpsomhed blandt andre deltagere eller kompleksiteten af problemet der skal løses.

Det sidste kapitel undersøger, hvordan brugen af crowdsourcing som innovationsmetode påvirker virksomheders innovationspræstation, og hvilke forhold der positivt påvirker dette forhold. Ved brug af innovationsdata på virksomhedsniveau fra Tyskland, finder dette kapitel en positiv sammenhæng mellem brugen af crowdsourcing som innovationsmetode og virksomheders innovationspræstation i de fleste empiriske modeller. Desuden præsenterer det bevis på, at dette forhold er positivt modereret af virksomhedernes digitale muligheder.

Afhandlingen indeholder flere teoretiske og ledelsesmæssige implikationer. Den bygger videre på tidligere forskning inden for samarbejde og crowdsourcing som en løsning til søgning efter fjern viden. Derudover giver den vejledning til ledere som forsøger at konstruere kvaliteten af crowdsourcing løsninger og deres organisationers evne til at drage fordel af disse.

Zusammenfassung

Crowdsourcing hat sich zu einer bekannten Methode entwickelt, die Unternehmen zur Akquirierung von unternehmensexternem Wissen als Teil ihres Innovationsprozesses nutzen. Hierbei fuehren Unternehmen einen Innovationswettbewerb durch, in dem Teilnehmende alleine oder in Kooperation mit anderen eine zu loesende Problemstellung bearbeiten. Anschliessend werden die erarbeiteten Loesungsvorschlaege evaluiert, mit dem Ziel, die besten Ideen in Innovationen zu transformieren.

Bisherige Literatur zu Crowdsourcing und Innovationswettbewerben betrachtet Kooperation und Wettbewerb als unterschiedliche Dimensionen. Wenig erforscht ist hingegen das Zusammenspiel beider Dimensionen und deren Auswirkungen auf den Erfolg des Innovationswettbewerbs auswirkt, sowie den Umstaenden, unter welchen Teilnehmende mit den anderen Wettbewerbenden kooperieren. Darueber hinaus kommen Studien hinsichtlich der Transformation von Innovationswettbewerbsergebnissen zu Innovationserfolg in Unternehmen zu widerspruechlichen Resultaten. Die vorliegende Dissertation adressiert diese Themen in drei Kapiteln.

Das erste Kapitel exploriert, wie sich Koopetition – d.h. die Kooperation unter Wettbewerbsbedingungen – auf die Ideenqualitaet in Innovationswettbewerben auswirkt. Dazu werden die Erkenntnisse eines Laborexperiments vorgestellt: Teilnehmende generierten unter verschiedenen Kooperations- und Wettbewerbsbedingungen Ideen zu einer realen Problemstellung.
Die Moeglichkeit der Kooperation fuehrte, im Vergleich zur Nicht-Kooperationsgruppe, durchschnittlich zu keinem positiven Effekt auf die Neuheit der Ideen. Jedoch hat diese einen positiven Effekt auf die Nuetzlichkeit und einen negativen auf die Durchfuehrbarkeit der Ideen. Bei Betrachtung der Effekte auf die besten Ideen, wird deutlich, dass die Effekte fuer die Nuetzlichkeit und Durchfuehrbarkeit gleichbleiben, aber die Anzahl der Ideen mit dem hoechsten Neuheitsgrad in der Kooperationsgruppe hoeher ist als in der Nicht-Kooperationsgruppe.

Das zweite Kapitel beleuchtet, wie und unter welchen Bedingungen Wettbewerbsstrukturen die Wahrscheinlichkeit, dass Individuen in Innovationswettbewerben kooperieren, beeinflusst. Interviews und zwei Experimente, die mit einer adaptiven wahlbasierten Conjoint- und Cluster-Ensemble-Analyse kombiniert sind, zeigen auf, dass ein hoeherer Grad an Wettbewerb die Wahrscheinlichkeit der Bereitschaft von Individuen zur Kooperation in Innovationswettbewerben signifikant reduziert. Dies ist vorwiegend darin begruendet, dass

Individuen unter diesen Voraussetzungen eher das Wissen anderer aufnehmen als ihr eigenes zu teilen. Treiber dieser Kooperationsentscheidungen lassen sich in zwei uebergeordnete Cluster teilen: Das eine Cluster besteht aus Teilnehmenden, die eine Ausnutzung ihres Wissens durch andere Teilnehmende befuerchten. Individuen in diesem Cluster haben eine hoehere Wahrscheinlichkeit zu kooperieren, wenn diese Angst durch das Wettbewerbsdesign adressiert (und im besten Fall beseitigt) ist. Das andere Cluster setzt sich aus Teilnehmenden zusammen, die entweder intrinsisch oder extrinsisch motiviert sind, in Verbindung mit anderen Faktoren, z.B. die bisherige Hilfsbereitschaft anderer teilnehmenden Individuen oder der Komplexitaet der Problemstellung.

Das letzte Kapitel prueft, was der Zusammenhang zwischen Crowdsourcing als Innovationsmethode und der Innovationsleistung von Unternehmen ist und welche Bedingungen diesen Zusammenhang positiv beeinflussen. Basierend auf Daten zu Innovationsaktivitaeten deutscher Unternehmen, findet dieses Kapitel, dass Crowdsourcing als Innovationsmethode in den meisten empirischen Modellen eine positive Beziehung zur Innovationsleistung von Unternehmen aufweist. Zudem zeigt sich, dass diese Beziehung durch digitale Faehigkeiten der Unternehmen positiv moderiert wird.

Die vorliegende Dissertation umfasst mehrere Implikationen fuer Theorie und Praxis. Sie erweitert die Forschung zu Koopetition und Crowdsourcing als eine Loesung fuer Distant Search. Darueber hinaus koennen die Resultate Managern als Richtlinie dienen, die Qualitaet von Innovationswettbewerbsergebnissen und den unternehmerischen Innovationserfolg zu verbessern.

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Introduction

Crowdsourcing has become a prominent external search method to generate inputs to organizations' innovation efforts (Afuah and Tucci 2012, Boudreau et al. 2011, Piezunka and Dahlander 2019, Huff et al. 2013, Jeppesen and Lakhani 2010). In the crowdsourcing process, organizations set up an innovation contest, post an innovation problem to a large crowd of diverse solvers, and typically offer a prize to motivate solvers to self-select into generating and then submitting their solution (Howe 2006, Ihl et al. 2016, Terwiesch and Xu 2008). Subsequently, organizations evaluate the received solutions and attempt to translate them into innovations (Blohm et al. 2013, Dahlander and Piezunka 2014, Pollok et al. 2019).

Research on the idea generation part of crowdsourcing examines why individuals decide to join and repeatedly contribute to crowdsourcing (e.g., Hofstetter et al. 2018, Lakhani and Wolf 2003), how they interact on crowdsourcing platforms (e.g., Füller et al. 2014, Hutter et al. 2011), and how incentives and competition can motivate individuals to exert the most idea generation effort (e.g., Boudreau et al. 2011, Körpeoğlu and Cho 2018, Terwiesch and Xu 2008). While this literature has immensely enriched our understanding in these aspects, a widespread design of crowdsourcing processes is not understood well enough: innovation contests in which individuals cooperate and compete with each other. This simultaneous cooperation and competition represent a situation of individual-level coopetition (cf. Bengtsson and Kock 2014). In these situations, individuals can voluntarily cooperate, meaning they can decide to share knowledge with other individuals (i.e., disclose their own idea or provide comments on other ideas) and absorb knowledge from other individuals (i.e., see others' ideas or receive comments on their own idea). Allowing individuals to cooperate in an innovation contest creates a paradoxical situation in which individuals can help others create a better idea, although they compete for the same prize. However, we know little about crowdsourcing processes that create a situation where individual-level cooperation and competition occur – especially regarding two important issues.

First, it is unclear whether allowing for cooperation in contests actually increases the performance outcomes. Literature on competition suggests that the effort of an individual determines an idea's quality (Boudreau et al. 2011, Körpeoğlu and Cho 2018, Terwiesch and Xu 2008). Literature on cooperation argues that allowing for knowledge recombination and learning effects increase idea quality (e.g., Bullinger et al. 2010, Hutter et al. 2011, Jin et al. 2021). However, in situations of simultaneous cooperation and competition, neither is effort the only idea quality determining factor any longer nor do individuals necessarily have an incentive to cooperate (Wasko and Faraj 2005).

Second, it remains unclear why individuals would cooperate when competing for the same prize (cf. Jarvenpaa and Majchrzak 2010, Wasko and Faraj 2005) and which role competition plays in individuals' decisions to cooperate. Literature suggests that individuals can be reluctant to cooperate (cf. Jarvenpaa and Majchrzak 2010, Wasko and Faraj 2005) because others may free-ride or they could lose their competitive advantage (Cabrera and Cabrera 2002, Sweeney 1973). Yet, there is some evidence that individuals cooperate despite competition (Bullinger et al. 2010, Riedl and Seidel 2018). The specific reasons for the decision to cooperate may further influence the type of cooperation and, consequently, the cooperation outcomes.

Once the crowd generated ideas, organizations need to evaluate and translate the ideas into innovation performance. However, these firm-level innovation performance effects are not well understood. We know that creating specific organizational roles, modes of communication, and decision rights can improve the use of external knowledge in an organization's innovation process (Blohm et al. 2013, Foss et al. 2011, Pollok et al. 2019). Yet, prior literature that examines the relationship between the use of crowdsourcing as an innovation method and innovation performance offers conflicting evidence. On the one hand, research shows that user ideas submitted to one firm achieved higher sales than those by experts (Nishikawa et al. 2013). On the other hand, crowdsourcing remains of low importance to firms (Chesbrough and Brunswicker 2014), often overwhelms firms with the task of evaluating ideas (Acar 2019, Blohm et al. 2013), and frequently fails (Piezunka and Dahlander 2015, 2020). Reasons for this conflicting evidence could be the challenges in evaluating the generated ideas and firms' absorptive capacity regarding idea assimilation and exploitation.

In sum, prior literature offers little guidance on how the paradoxical tension between individual-level cooperation and competition affects the idea generation process and outcomes of crowdsourcing and what the firm-level performance outcomes of evaluating and translating those generated ideas are. Yet, it is important to examine these issues in order to advance our understanding of crowdsourcing as an emerging organizational form for firms' innovation efforts (Afuah and Tucci 2012, Dahlander and Wallin 2006, Majchrzak and Malhotra 2020b). The following sections summarize the three thesis papers addressing these research gaps.

Thesis overview

This thesis examines processes and performance effects in crowdsourcing. More specifically, it investigates how the design of crowdsourcing processes can help to generate ideas and solutions (individual level) that the organization can then evaluate and translate into innovation performance (firm level). Table 1 provides an overview of the thesis chapters. Chapter 1 examines how enabling cooperation between competing individuals influences idea quality and how different cooperative processes alter this idea quality. Chapter 2 focuses on the influence of competition on how individuals cooperate and the drivers behind these decisions. Moving to the firm level, Chapter 3 studies the relationship between the use of crowdsourcing as an innovation method and innovation performance, as well as boundary conditions that positively influence this relationship.

Table 1: Overview of the thesis chapters

Title	**Research Question**	**Unit of Analysis**	**Main outcome variables**	**Data**	**Data analysis approach**
C1: Individual-level coopetition in innovation contests: processes and outcome effects	How does coopetition in innovation contests affect innovative outcomes, i.e., the quality of ideas generated?	Individual level	Idea quality (novelty, user benefit, feasibility)	Lab experiment (N=294)	OLS, qualitative content analysis
C2: The influence of competitive reward structures on cooperative behavior in innovation contests: experimental evidence	How do competitive reward structures in innovation contests influence the likelihood that individuals will choose to cooperate, and what are the conditions under which competition affects the cooperative behavior of contestants?	Individual level	Willingness to cooperate and configuration of attributes that influence the decision to cooperate	Interviews (N=15) and online experimental vignette studies (Study 1 N=405; Study 2 N=562)	OLS, adaptive choice-based conjoint analysis, cluster ensemble analysis
C3: Crowdsourcing and innovation performance: The moderating role of digital capabilities	How does the use of crowdsourcing as an innovation method impact firms' innovation performance and which conditions positively influence this relationship?	Firm level	Innovation performance (innovation sales)	Survey data (N=1,657)	Tobit

Chapter 1 – Individual-Level Coopetition in Innovation Contests: Processes and Outcome Effects

Crowdsourcing activities are typically organized as innovation contests in which individuals compete for a prize awarded to the best solution (Körpeoğlu and Cho 2018, Terwiesch and Xu 2008). However, many of these innovation contests have enabled cooperative features that allow individuals to reveal their own ideas, view others, and provide and receive comments. Despite the growing interest in understanding innovation contests in the innovation literature (Afuah and Tucci 2012, Boudreau et al. 2011, Jeppesen and Lakhani 2010, Majchrzak and Malhotra 2020b), we know little about crowdsourcing processes that enable situations in which individuals cooperate and compete.

Turning to the literature on competition and cooperation for guidance on how their combined effects play out, we find that there is research on each of the dimensions separately but not on their combination. For example, literature on competition suggests that competition can increase the number of participants and their effort exertion (Boudreau et al. 2011, Körpeoğlu and Cho 2018, Terwiesch and Xu 2008), leading to higher individual performance (Moldovanu and Sela 2001). Interestingly, literature on cooperation paints a less clear picture of the effect direction. While cooperation can allow individuals to see other ideas that stimulate their creativity (Dugosh et al. 2000, Riedl and Seidel 2018) and enable knowledge recombination (Fleming et al. 2007, Kogut and Zander 1992), receiving feedback can decrease the quality of the best ideas (Wooten and Ulrich 2017) and lead individuals to fixate on the ideas of others, thus, constraining their creativity (Hofstetter et al. 2021). The combined effects of cooperation and competition on idea generation outcomes are even more intricate. Individuals have no direct incentive to cooperate with others (Wasko and Faraj 2005) as enhancing other ideas reduces their own chances of winning (Landkammer and Sassenberg 2016). Some evidence even suggests that individuals might sabotage others' idea generation efforts (Harbring and Irlenbusch 2011). In sum, it is unclear what the influence of individual-level coopetition on idea quality is.

To shed light on this issue, we conduct a lab experiment (2 x 2) with 294 participants. In the lab experiment, we initiate an innovation contest in which we manipulate the opportunity to cooperate as well as the level of competition. Participants in the group that cooperated under competition could see other participants' ideas and provide or receive comments on ideas. The generated ideas are then evaluated by an expert and user jury on the idea quality dimensions of novelty, user benefit, and feasibility. We find that individual-level cooperation under competition has no average effect on novelty but a positive on user benefit and a negative on feasibility. Yet, organizations can only implement a limited number of ideas, meaning that the distribution of the highest-rated ideas should be of particular interest (Girotra et al. 2010, Terwiesch and Ulrich 2009). Indeed, when considering only the ideas with the highest novelty rating, we see slightly more novel ideas among the groups where individuals could cooperate under competition.

In Study 2, we perform a qualitative content analysis of the ideas that the individuals saw and the type of comments they received. We do so to understand how the underlying cooperation under competition process impacts the subsequent idea quality. Our results suggest that individual-level cooperation under competition processes, which are characterized by ideas and comments containing new knowledge in relation to the individual's own idea, inspire more novel but less feasible ideas. Processes, in which questions are asked, relate to ideas with higher user benefit and feasibility.

Chapter 2 – The Influence of Competitive Reward Structures on Cooperative Behavior in Innovation Contests: Experimental Evidence

Cooperating with others in innovation contests constitutes a public good dilemma (Cabrera and Cabrera 2002). While everyone can profit from the shared knowledge without depleting it (Olson 1965), there is no strict necessity to contribute themselves (Sweeney 1973), which might mean incurring costs or losing a competitive advantage (Cabrera and Cabrera 2002). Social interdependence theory – concerned with the differences in interaction between individuals depending on their goal relation – suggests that cooperation results from cooperative reward structures (Deutsch 1949, Tjosvold 1989), and competition reduces an individual's willingness to do so (Beersma et al. 2003). However, these arguments contrast with widespread evidence of individuals cooperating in innovation contests (Riedl and Seidel 2018).

Previous literature offers a few suggestions for the motivations behind this behavior: cooperation with others may enable learning and, thus, increase the winning chances, or the contest may aim at solving a pro-social and not-for-profit problem (e.g., Füller et al. 2014, Jin et al. 2021, Kathan et al. 2015, Majchrzak and Malhotra 2020b). We suggest that the decision to cooperate under competition is made by individuals considering a complex set of interrelated attributes. This chapter investigates how competitive reward structures in innovation contests influence the likelihood that individuals will choose to cooperate and what the conditions are under which competition affects the cooperative behavior of individuals.

Drawing on literature discussing competition (Murayama and Elliot 2012), cooperation (Cabrera and Cabrera 2002), and knowledge disclosure (Foege et al. 2019), we predict that an increase in competition decreases individuals' willingness to cooperate in innovation contests. Yet, cooperation consists of sharing and absorbing ideas and knowledge. We argue that the decrease in individuals' willingness is stronger for sharing ideas and knowledge (i.e., revealing their own idea or providing comments on other ideas) than absorbing ideas and knowledge (i.e., from the other ideas seen and comments received). We test these predictions in Study 1 by conducting an experimental vignette study (3 x 1) with 405 participants in which we vary the level of competition (no, low, and high). Our results indicate that competition negatively impacts individuals' willingness to cooperate. This negative effect is stronger for sharing ideas and knowledge with other contestants than absorbing ideas and knowledge.

In Study 2, we then follow a configurational approach that allows us to study the combined effect of configurations of interdependent attributes on individuals' decisions to cooperate. It is necessary to study the combined effect of attributes rather than exploring drivers individually because individuals' decisions in these innovation contests are likely to be dependent on a set of attributes, such as the individual (e.g., motivation to participate in the innovation contest), the other individuals in the contest (e.g., helpfulness of the other individuals), and the contest itself (e.g., cooperation rewards). In the first step, we conduct a literature review and interview 15 participants from real-world innovation contests to identify and conceptualize the attributes of this cooperation decision. We then perform an adaptive choice-based conjoint (ACBC) study and a cluster ensemble analysis based on these attributes. Our results from 562 study participants accentuate that the decision to cooperate with other contestants relies on a bundle of attributes. Interestingly, the fear of knowledge misappropriation by other individuals in the innovation contest is a primary concern to individuals regardless of the level of competition, even in the no-competition group. While extrinsic motivation can drive individuals to cooperate when competition is low, it does not suffice when competition is high. Instead, when competition is high, intrinsic motivations play an essential role in the decision to cooperate.

Chapter 3 – Crowdsourcing and Innovation Performance: The Moderating Role of Digital Capabilities

Crowdsourcing is considered a solution to distant search because it provides the solution-seeking firm with a large number of diverse ideas that are comprised of distant knowledge (Afuah and Tucci 2012, Jeppesen and Lakhani 2010). Yet, it is not understood well enough whether firms are able to translate these ideas into innovation performance. On the one hand, there is evidence that crowdsourcing ideas may lead to higher sales revenues and gross margins (Nishikawa et al. 2013). On the other hand, research highlights the challenges of crowdsourcing as it is ranked as a relatively unimportant innovation method (Chesbrough and Brunswicker 2014) and often overstrains firms' ability to process and incorporate the ideas (Blohm et al. 2013). Further, there are many examples of crowdsourcing efforts simply failing (Acar 2019, Dahlander and Piezunka 2014, 2020). This chapter investigates how using crowdsourcing as an innovation method impacts firms' innovation performance and which conditions positively influence this relationship.

Building on literature discussing external search (Katila and Ahuja 2002, Laursen and Salter 2006) and crowdsourcing (Afuah and Tucci 2012, Poetz and Schreier 2012), this chapter argues that the outcomes of crowdsourcing should improve firms' innovation performance. However, this is unlikely to be the case for all firms because crowdsourcing puts high information-processing demands on firms (Piezunka and Dahlander 2015, Simon 1978, Tushman and Nadler 1978). More specifically, when using crowdsourcing, firms typically have to evaluate a large number of diverse and distant ideas and translate them into innovation performance. Prior literature shows that firms often struggle with this evaluation (Acar 2019, Piezunka and Dahlander 2015) or lack the capabilities to translate the received outcomes into innovation performance (Cohen and Levinthal 1990). Synthesizing literature on capabilities (Grant 1996) and the digitalization of organizations (Nambisan et al. 2019, Wu et al. 2020), I theorize that digital capabilities can assist firms in overcoming these information-processing limitations.

This chapter uses the Mannheim Innovation Panel Data from 2019 with a sample of 1,657 German firms. The data provide information on a firm's use of crowdsourcing, the extent of digital capabilities, and innovation performance. I find that the use of crowdsourcing as an innovation method positively relates to firms' innovation performance in most empirical models. Further, I provide evidence that digital capabilities positively moderate this relationship, indicating that firms with higher levels of digital capabilities are more able to translate crowdsourcing outcomes into innovation performance.

Contributions

This thesis advances our understanding of crowdsourcing processes and outcomes in several ways. First, Chapter 1 highlights the heterogeneity in the effect of individual-level coopetition on the different idea quality dimensions. This challenges literature on community-based crowdsourcing, which accentuates the advantages of cooperation (e.g., Füller et al. 2014, Majchrzak and Malhotra 2020a), and innovation contests, which emphasizes the benefits of competition (e.g., Boudreau et al. 2011, Terwiesch and Xu 2008). Instead of separating cooperation and competition, this chapter reveals how the interaction between the two impacts crowdsourcing outcomes. This also extends literature advising managers on how individuals should be organized to create the knowledge firms need and the trade-offs that must be considered (Nickerson and Zenger 2004).

Second, Chapter 1 presents a model of individual-level coopetition describing how and under which conditions the three idea quality dimensions are affected by individual-level coopetition. It also uncovers the relationship of these dimensions to the differences in the type of feedback individuals receive. These insights advance the literature on innovation contests (Hofstetter et al. 2021, Jin et al. 2021) and can be transferred to other contexts of individual coopetition, such as employees competing for promotions while cooperating on daily tasks (Banks et al. 2021, DeVaro 2006).

Third, chapter 2 deepens our insights into the interaction between competition and various innovation contest configurations and the way it influences how and when individuals – who are connected through competitive social interaction and located outside the boundaries of organizations – decide to become involved in coopetition. This advances social interdependence theory (Deutsch

1949, Johnson and Johnson 1989, Johnson 2003) and literature on managing and organizing innovation (Argyres and Silverman 2004, Dahlander and Frederiksen 2012). Managers seeking to adjust the balance between cooperation and competition in their crowdsourcing efforts may also benefit from these results as they offer guidance on increasing or decreasing cooperation in innovation contests.

Moreover, the findings in Chapters 1 and 2 extend the firm-level concept of coopetition to the individual level. While research on coopetition has predominantly focused on the firm (Cassiman et al. 2009, Gnyawali and Park 2011, Ritala and Hurmelinna-Laukkanen 2013), unit or team level within organizations (An et al. 2020, Baumann et al. 2019, Tsai 2002), the results of these two chapters highlight the processes and outcomes of individual-level coopetition that occur in innovation cooperation outside of organizational boundaries.

Lastly, prior literature presents conflicting evidence on the relationship between the use of crowdsourcing as an innovation method and firms' innovation performance (cf. Acar 2019, Blohm et al. 2013, Nishikawa et al. 2013), leaving uncertainty about its effect on organizations' innovations efforts. The findings in Chapter 3 provide insights into this relationship and, more importantly, offer reconciliation for the conflicting evidence. Namely, it helps understand how boundary conditions – the extent of firms' digital capabilities – influence firms' ability to translate crowdsourcing outcomes into innovation performance and, thus, advances the literature on external search (Chesbrough 2003, Laursen and Salter 2006) and crowdsourcing (Piezunka and Dahlander 2015, Poetz and Schreier 2012). These findings may also inform managers' decisions of when their organization should engage with the use of crowdsourcing as an innovation method (Afuah and Tucci 2012, Boudreau and Lakhani 2013).

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Chapter 1 – Individual-level Coopetition in Innovation Contests:

Processes and Outcome Effects

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1.1. Abstract

Many organizations complement their search for innovation by outsourcing innovation-related tasks to external "crowds". Set up as an innovation contest in which participants can win a prize, individuals self-select into working on and submitting their solution to the problem independently from each other. In many contests, individuals can also cooperate, i.e., they can see others' ideas and comment on them after which they can decide whether or not to incorporate the knowledge into their submission. This creates a situation of individual-level coopetition, fundamentally changing the nature of the contest with unclear consequences for the quality of innovative outcomes. In this paper, we investigate individual-level coopetition in innovation contests and study processes and outcome effects within this emerging organizational form of innovation search. We report evidence from a lab experiment with 294 participants in which coopetition exhibits no effect on the novelty of an idea while it has a positive effect on its user benefit and a negative effect on its feasibility. Further, we explore the underlying coopetition processes and identify patterns of knowledge exchange based on data from a qualitative content analysis. We find marked differences in the processes driving the three dimensions of outcome quality, suggesting that cooperation between the contestants involves trade-offs.

Keywords: innovation contests, coopetition, idea quality, crowdsourcing, experimental study

1.2. Introduction

In recent years, organizations have begun to complement their search for innovation by outsourcing innovation-related tasks to external "crowds" (e.g., Afuah and Tucci 2012, Bayus 2013, Piezunka and Dahlander 2019, Riedl and Wooley 2017). Typically set up as a contest, an organization posts an innovation problem to a large and diverse crowd of potential solvers who self-select into working on and submitting their solution to the problem independently from each other (Terwiesch and Xu 2008). While these individuals compete for the prize awarded to the best solution, they can typically also cooperate with each other, i.e., they can disclose their own and see others' ideas, provide and receive comments on ideas, and share knowledge with each other. Prior theoretical and empirical research on innovation contests commonly adopts a "winner-takes-all" incentive structure in which individuals cannot cooperate (Körpeoğlu and Cho 2018, Terwiesch and Xu 2008). Yet, allowing the contestants to cooperate fundamentally changes the nature of the contest. On the one hand, the opportunity to cooperate gives participants the chance to be cognitively stimulated by the ideas they see (Dugosh et al. 2000, Riedl and Seidel 2018) and recombine diverse knowledge from others' ideas and received feedback (Fleming et al. 2007, Kogut and Zander 1992). On the other hand, seeing other ideas can lead to fixation effects that constrain creativity (Hofstetter et al. 2021) while feedback reduces the variance in idea quality and often disimproves the best ideas (Wooten and Ulrich 2017). These effects are further complicated as cooperation also has repercussions for competition. Contestants lack the incentive to share their knowledge because they may improve others' ideas and decrease their own winning chances (Wasko and Faraj 2005, Landkammer and Sassenberg 2016). They may also withhold knowledge against better judgement or even sabotage others by offering ill-intentioned advice (Harbring and Irlenbusch 2011). Unless the contest mitigates competition by either allowing for team submission (Jin et al. 2021) or rewarding cooperative behavior itself (Majchrzak and Malhotra 2016), the effect of individual-level cooperation on the quality of the outcomes remains unclear.

Although innovation contests have become a phenomenon of practical relevance and high theoretical interest (e.g., Afuah and Tucci 2012, Boudreau et al. 2011, Jeppesen and Lakhani 2010, Riedl and Seidel 2018), theory on innovation contests as an emerging organizational form in which individuals compete and cooperate at the same time is scarce. On the organizational level, "coopetition", defined as a relationship between two or more firms that simultaneously engage in cooperation and competition (Bengtsson and Kock 2014), has frequently been studied as an arrangement that enables knowledge sharing and contributes to an organization's innovation performance (Cassiman et al. 2009, Gnyawali and Park 2011, Ritala and Hurmelinna-Laukkanen 2013). Coopetition is also a pervasive phenomenon within the boundaries of the firm. Organizational units, departments or teams seek to learn from each other and take advantage of knowledge produced by other units but they also compete for internal resources as well as status and rewards that often depend on how well they perform compared to other units of the same organization (An et al. 2020, Baumann et al. 2019, Ghobadi and D'Ambra 2012, Luo et al. 2006, Tsai 2002). Extant theory on firm or unit-level coopetition, however, provides little guidance for individual-level coopetition. On the one hand, coopetition between organizations or subunits is typically characterized by repeated interaction supported by organizational structures or contractual arrangements that govern knowledge sharing and protection mechanisms (Jones et al. 1997, Wu 2008, Estrada et al. 2016). Interactions in innovation contests, in contrast, are mostly non-recurring and temporary (Hofstetter et al. 2018) without formal agreements between contestants that could mitigate appropriation hazards (Foege et al. 2019). On the other hand, while organizations and subunits engage in coopetition with others they know and trust (Poppo et al. 2008), contest participants typically do not know each other. This lack of theorizing about individual-level cooperation under competition consequently limits our understanding of the contestants' ability to generate superior contributions to organizations' innovation search efforts.

In this paper, we ask how coopetition in innovation contests affects innovative outcomes, i.e. the quality of ideas generated. Due to the lack of theoretical priors, we follow a question-driven approach and answer our research question in two steps. First, we conduct a laboratory experiment in which we manipulate the possibility to cooperate as well as the competitive conditions in an innovation contest. Half of the participants are randomly assigned to the cooperation group, i.e., they have the possibility to cooperate with their competitors during the idea generation process, while the other half develops ideas on their own. In addition, participants in both groups are randomly assigned to either a low-competition or a high-competition treatment, creating a 2x2 experimental setting. In line with previous research on the quality of crowdsourcing outcomes (e.g., Kornish and Ulrich 2014, Majchrzak and Malhotra 2016, Poetz and Schreier 2012), we ask an expert and a user jury to evaluate the quality of all ideas created in the four experimental groups along three dimensions: novelty, user benefit, and feasibility. The outcome effects of individual-level coopetition turn out to be mixed. On average, individual-level coopetition has no effect on novelty, a positive effect on user benefit, and a negative effect on feasibility. Looking at the very best ideas only, coopetition leads to slightly more novel ideas. The effects on user benefit and feasibility remain unchanged.

Second, to better understand the underlying coopetition processes and how they influence the generation of innovative outcomes, we present results from a qualitative content analysis. Here, we analyze how seeing the ideas from others and how the type of feedback comments received lead the participants to revise their initial ideas as well as how these processes relate to idea quality. Most interestingly, we identify ideas and comments that contain new knowledge as beneficial to idea novelty while asking questions is associated with higher user benefit and feasibility. Feasibility, however, disimproves when participants receive more comments that contain new knowledge.

The contribution of our research is at least twofold. First, innovation contests constitute an emerging organizational form that has garnered significant theoretical interest (e.g., Afuah and Tucci 2012, Boudreau et al. 2011, Jeppesen and Lakhani 2010, Riedl and Seidel 2018), yet the role of individual-level coopetition in such innovation search efforts remained undertheorized, leading to unclear predictions about the contestants' ability to generate innovative outcomes. Innovation contests have been characterized as loosely coupled organizational forms (Dahlander and Wallin 2006, Franke et al. 2013) that allow firms to obtain highly innovative solutions in exchange for a modest compensation (Poetz and Schreier 2012, Terwiesch and Ulrich 2009). But they are also considerably less stable and reliable than other forms of organization for the generation of innovation. Individuals self-select into temporary and decentralized problem-solving activities with very low entry and exit barriers (Dahlander and Frederiksen 2012). Our research offers insights into the differential effects of individual-level coopetition on the relevant dimensions of innovative outcomes and maps the underlying coopetition processes, challenging both literature on the benefits of competitive innovation contests (e.g., Boudreau et al. 2011, Terwiesch and Xu 2008) and literature on community-based crowdsourcing that strongly advocates for the benefits of cooperation (e.g., Füller et al. 2014, Majchrzak and Malhotra 2020). Since much of the existing literature on crowdsourcing and innovation contests treats competition and cooperation as two separate dimensions, our research contributes to understanding how these two dimensions interact and how this interaction plays out in terms of performance implications. In doing so, we extend the literature on how managers should organize individuals outside the firm to generate knowledge that the firm seeks (Nickerson and Zenger 2004, p. 618). Investigating outcome effects separately on novelty, user benefit and feasibility, this study moreover provides insights into trade-offs involved in enabling individual-level coopetition. Subject to a firm's innovation objectives, enabling individual-level coopetition may or may not be the best way to organize external individuals to contribute their knowledge.

Second, we identify a model of individual-level coopetition in innovation contests that we derive from our empirical studies. Prior coopetition research has largely been focused on the firm level (Cassiman et al. 2009, Gnyawali and Park 2011, Ritala and Hurmelinna-Laukkanen 2013) or on the level of units, departments or teams within the boundaries of organizations (An et al. 2020, Baumann et al. 2019, Ghobadi and D'Ambra 2012, Luo et al. 2006, Tsai 2002) but disregarded the individual level despite the prevalence of coopetition dynamics in new forms of engaging with individuals outside the firms' boundaries in search of innovation (Hofstetter et al. 2021, Jin et al. 2021). Our research offers insights on how and under which conditions individual-level coopetition affects different dimensions of idea quality, uncovering the heterogeneity in the effects of feedback received in a contest. In that sense, our research addresses a void in extant coopetition literature that has so far been silent about individual-level outcomes carrying importance for an organization's innovation performance. Moreover, our insight into individual-level coopetition can inform other coopetitive contexts, for example, when individual employees compete for promotions or resources but cooperate on day-to-day tasks (Banks et al. 2021, DeVaro 2006), or when researchers compete for publications, tenure, and grants but cooperate by giving feedback at conferences and seminars (Gerosa 2001, Leydesdorff et al. 2014).

1.3. Background

1.3.1. Innovation contests, cooperation and the quality of innovative outcomes

Crowdsourcing ideas to solve innovation problems has become a widely used open innovation method that allows organizations to tap into distributed knowledge and diverse skills outside their boundaries (Afuah and Tucci 2012, Leimeister et al. 2009). The goal is to identify the highest performing ideas and to incorporate them into the innovation process (Girotra et al. 2010, Terwiesch and Ulrich 2009). Prior research has mostly conceptualized the quality of an idea along three dimensions: an idea's novelty, user benefit, and feasibility (Blohm et al. 2013, Zhu et al. 2019). Novelty describes the degree to which an idea is new compared to existing solutions. User benefit measures the value of the idea in terms of its ability to solve the underlying problem. Feasibility depicts the ease with which an idea could be translated into a commercial product (Bayus 2013, Poetz and Schreier 2012). It takes into account technology, cost, and manufacturability (Kudrowitz and Wallace 2013) and the degree to which the idea is legally, socially, and politically acceptable (Dean et al. 2006). Crowds have been found to generate ideas that can complement or even outperform those developed internally, for example by a firm's internal research and development (R&D) unit, on dimensions such as novelty and user benefit, but not on feasibility (Poetz and Schreier 2012).

The more complex the contest's underlying challenge is, the more effort is required by the contestants (Nakatsu et al. 2014) and the less likely it gets solved (Afuah and Tucci 2012, Dahlander et al. 2019). Increased competition typically elevates participants' effort in innovation contests (Moldovanu and Sela 2006, Terwiesch and Xu 2008), especially among those who are highly skilled (Körpeoğlu and Cho 2018), and this increase in effort positively relates to an increase in the performance outcome. Boudreau et al. (2011) highlight that higher competition can particularly nurture the generation of the desired extreme value outcomes. These outcomes are of special interest in innovation contests, as only a limited number of the best ideas can be implemented by the contest organizer (Girotra et al. 2010, Terwiesch and Ulrich 2009).

To facilitate solutions for more complex problems, recent applications of innovation contests enable the contestants to cooperate with each other. Kaggle.com, an online contest platform for data scientists, statisticians, and machine learning experts, for example, provides a discussion board where contestants can, but do not need to share their coding scripts, so that others can read, discuss, vote for, and develop them prior to submission. Hofstetter et al. (2021) report that almost 80% of all the contests listed on the contest platform 99designs.com are organized as open contests that enable cooperation, making all submissions transparent and accessible to all participants.

Our conceptualization of cooperation in innovation contests builds on literature that emphasizes the relational behavior between interacting individuals who exchange resources such as knowledge, discuss problems, or provide assistance, support and encouragement (Argyle 1991, Tjosvold 1988). Hence, we define cooperation in innovation contests as an interactive and relational behavior between individuals in order to achieve the individuals' goal (Bullinger et al. 2010, Chen et al. 1998, Milton and Westphal 2005), i.e., participants can disclose their ideas and see others', they can comment on them or receive comments on their own ideas. However, the interaction between individuals does not have to be symmetrical nor necessarily involve individual benefits (Milton and Westphal 2005, Thomson and Perry 2006). Moreover, cooperation is distinct from collaboration in innovation contests where individuals interact to work in teams or communities to achieve a joint outcome (Thomson and Perry 2006). Kaggle.com, for example, offers participants the option to continue competing individually or form a team that works together as one contestant which mitigates competition (Jin et al., 2021). In that sense, we focus on cooperation and not collaboration in innovation contests. Participants still compete individually for the prize, creating a situation of individual-level coopetition.

1.3.2. Implications of individual-level coopetition for generating innovative solutions

Enabling cooperation in innovation contests provides individuals with the opportunity to recombine knowledge. Knowledge recombination is the fruitful uniting of existing knowledge in a new way to create novel solutions (Nelson and Winter 1982, Schumpeter 1942). It facilitates successful innovation, especially if the knowledge recombined is diverse (Singh and Fleming 2010). This is particularly interesting in crowdsourcing, as its problem solving mechanism relies on activating self-selection among large numbers of (potential) solvers with diverse backgrounds (Boudreau and Lakhani 2013).

Prior research on collaborative crowdsourcing investigates how crowds self-organize and engage in a process of dis-aggregation and re-aggregation of knowledge elements from individual crowd members (Majchrzak et al. 2021, Riedl and Woolley 2017). Members of a crowd contribute bits and pieces to develop joint solutions. Particularly when participants share creative associations and paradoxes with each other, ideas of high quality can emerge (Majchrzak and Malhotra 2020, Malhotra and Majchrzak 2019). However, the submission of a joint solution also eliminates the competition among individual contestants for the prize. Moreover, making contributions to the joint outcome is oftentimes rewarded directly (Majchrzak and Malhotra 2016). While these are useful insights, it is unclear how knowledge recombination unfolds under competitive conditions.

Similarly, literature on individual creativity provides inconclusive evidence on the performance effects of cooperation between individuals in general and particularly under competitive conditions. On the one hand, seeing other ideas can be cognitively stimulating, thus increasing creativity and idea generation performance (Dugosh et al. 2000, Fink et al. 2012, Nijstad et al. 2002). On the other hand, seeing other ideas can lead to fixation effects that harm individuals' creative performance (Kohn and Smith 2011, Moreau and Dahl 2005). Hofstetter et al. (2021) find that this constraining effect is more pronounced the more ideas individuals see during the ideation process. Allowing for other individuals to be present can furthermore be socially inhibiting by "arousing, narrowing attention and reducing creative performance" (Hofstetter et al. 2021, p. 97). Investigating the role of feedback, Wooten and Ulrich (2017) find that directed feedback, i.e., in-process feedback given on the quality of an idea shortly after its submission, only increases the quality of the worst ideas in contests that allow for repeated entries. Hofstetter et al. (2018) find that positive competence feedback from the contest organizer helps keeping highly able individuals motivated and available for future challenges, whereas the number of likes and comments from peers positively influences the creative effort in successive contests.

More fundamentally, allowing participants to cooperate changes the nature of the innovation contest. Contest participants can free-ride on the knowledge being shared, so that they may refrain from sharing knowledge in the first place (Kathan et al. 2015, Wasko and Faraj 2005). Moreover, by sharing knowledge, individuals risk improving the performance of other participants without reaping benefits for themselves (Landkammer and Sassenberg 2016, Milton and Westphal 2005). Even when participants do comment on others' ideas, the quality of these comments varies significantly, with the majority of participants simply offering support or rather arbitrary comments (Füller et al. 2014). In a similar vein, allowing participants to cooperate can lead to sabotage that aims at decreasing other participants' performance (Harbring and Irlenbusch 2011). In fact, Jin et al. (2021) document that knowledge sharing features on Kaggle.com negatively impact the contestants' performance unless the shared knowledge is of high quality and generativity.

In that sense, prior literature provides inconclusive evidence on the role of individual-level coopetition for idea quality. Research most related to ours has gained insights on the effects of seeing other's ideas (Hofstetter et al. 2021) or sharing knowledge (Hutter et al. 2011, Jin et al. 2021) but either disregards the competitive dynamics or largely eliminates competition by allowing individuals to collaborate and to make a joint submission. Cooperation facilitates knowledge recombination and cognitive stimulation but may also lead to cognitive fixation and a disimprovement of one's own ideas. Competition increases effort and generates more extreme values but may also lead participants to withhold knowledge or even to sabotage others. To address these complexities, we investigate the baseline effect of cooperation under competitive conditions (individual-level coopetition) on idea quality first before we provide an in-depth analysis of the coopetition dynamics that unfold during the process to derive a model of individual-level coopetition in innovation contests.

1.4. Methods

We examine the causal effects of individual-level coopetition on innovative outcomes using a lab experiment in which participants generated ideas to solve a real-world problem and to submit their ideas to an innovation contest. We recruited participants from the subject pool of the Centre for Experimental Economics at the University of Copenhagen, which also provided the infrastructure for conducting the experiment, i.e., a computer laboratory with web-based interfaces. All participants received a show-up fee of 150 DKK (about 22.50 USD) as a basic compensation for their effort and potentially a prize should their idea win the contest. A total of 294 subjects participated across 18 experimental sessions over a period of 6 months. Participants had an average age of 25 years, slightly more than half of them identified as female, and around 28% had a Master's or higher educational degree.

1.4.1. Experimental procedure and treatments

The lab experiment applies a 2×2 between-subjects design to investigate the performance effects of cooperation (vs. no-cooperation) across two competition conditions (high competition vs. low competition); the distribution of participants across this design is described in Table 2.[1] Upon arrival at the lab, participants drew a number that allocated them a computer seat in one of two computer rooms. Once logged on, they were randomly assigned to the four main experimental groups.

[Insert Table 2 about here]

[1] Due to the Covid-19 lockdown rules we were not able to conduct the final lab sessions in the low-competition conditions, which leads to an unbalanced sample with less participants in these groups. As a robustness check we reran some analyses with a balanced sample that includes 48 observations (the lowest number in the full sample) in each experimental group (for more details see the remarks after the respective analysis).

Participants were also asked to answer survey questions before and after the idea generation process (Figure 1). The survey included questions on relevant alternative explanations that have been found to directly affect idea quality, relevant controls, and manipulation checks.

[Insert Figure 1 about here]

Experimental task. The challenge given to participants was a creative idea generation task, in which participants needed to find a solution to a university's bicycle parking problem.[2] This is a variation of the automobile parking problem that has been used widely in other idea generation experiments (e.g., Connolly et al. 1990, Gettys et al. 1987). To increase the external validity of the task, we opted for bicycle (vs. automobile) parking, as cycling is an important means of transportation in Copenhagen and congested bicycle parking an omnipresent real-world problem (e.g., Otzen 2014). Addressing ecological validity (Williams et al. 2019), the task is also similar in its familiarity and structure to problems on real crowdsourcing platforms (see, for example, a recent challenge on OpenIDEO (2020) that stated: "Help tackle retail bag waste and redesign the way goods are carried home").

Idea generation process and cooperation treatment. The idea generation process consisted of three stages (Figure 1). In stage 1, each participant was asked to generate and then submit an initial idea six minutes after having read the task and the contest rules (only one idea could be submitted per participant). Ideas could be described and submitted in the form of text only and were not limited in length. After submission of the initial idea, we randomly assigned participants to the cooperation or the no-cooperation treatment (n=147 participants in each group) to enter stage 2. We operationalized cooperation by randomly assigning each participant in the cooperation groups to three to four other participants who were currently present in the lab, creating knowledge exchange options in sub-groups of four to five participants. Thus, participants in the cooperation groups saw initial ideas from three to four other participants and were asked to anonymously and voluntarily give feedback (and receive feedback) to (from) the same three to four participants. We intentionally limited the number of potential cooperation partners to increase the likelihood that most, if not all, ideas received feedback comments. Moreover, this approach increases the external validity of our lab study by

[2] We tested and refined the formulation of the task description in a pre-test with n=49 participants (see Footnote 6 for details). To account for the effects of problem complexity on idea generation performance in crowdsourcing, we manipulated the complexity of the task description as outlined in the section on the measurement of control variables. For the detailed descriptions of the bicycle parking problem, see Appendix 1.

enabling participants to share and receive actual ideas and comments to/from other participants, similar to what happens on a real-world crowdsourcing platform that enables individual-level coopetition.

In total, the 147 participants in the cooperation groups provided 535 comments in the form of text, such that each participant received an average of 3.6 comments on their initial idea.[3] Participants in the cooperation groups were able to spend eight minutes on seeing others' initial ideas and commenting on them as well as three minutes on reading the comments they received on their own initial idea. In parallel, participants in the no-cooperation groups had the chance to individually reflect on their own initial idea for three minutes. Finally, participants in all experimental groups could decide whether or not to revise their initial idea and submit a revised (or the original) version of their idea within six minutes in stage 3. Out of the 147 participants in the cooperation groups, only 16 participants had decided not to revise their idea compared to 41 out of 147 participants in the no-cooperation groups (chi2 (1, N=294)=13.6, p=0.000), indicating that significantly more participants in the cooperation groups decided to revise their initial idea as compared to participants in the no-cooperation groups.[4] In order to standardize the conditions, the time available for idea generation and revision was strictly enforced in all groups by the web-based interface.

Competition treatment. We manipulated the level of competition in the contest by following Ehrenberg and Bognanno (1990) and Liu et al. (2014) who argue that the level of monetary incentives influences competition in contests. We explored the appropriateness of different amounts of prize money in a pilot study with n=148 participants. Results from this pilot study led us to choose two reward levels in our contest: DKK 250 (about 40 USD) in the low-competition condition and DKK 2,500 (about 400 USD) in the high-competition treatment as the prize for the best idea. In total, ten lab sessions with 191 participants were conducted in the high-competition condition and eight sessions with 103 participants in the low-competition condition.[5] It is important to note that there were no incentives for cooperation in the cooperation groups. Whether or not participants actually

[3] All but one out of the 147 participants in the cooperation groups answered all three questions regarding the cooperation functionalities (see other ideas, give feedback, and receive feedback) correctly, i.e., the manipulation check confirms the successful manipulation of our cooperation treatment.

[4] There is no difference in the revision decision of participants in the low and high competition groups (chi2 (1, N=294)=0.000, p=0.992).

[5] As a manipulation check, we asked participants about the prize money for winning the contest. All but eight out of the 294 participants answered correctly, indicating that our competition treatment worked. Removing these eight participants does not change the results we report in the following analysis.

shared comments and integrated feedback from them or incorporated knowledge from seeing other participants' ideas in the cooperation groups was entirely voluntary. Still, almost all participants decided to cooperate. For example, 99% of all participants left at least one comment on another idea, while 78% left at least one comment and also incorporated knowledge from either seeing other ideas or receiving feedback from others. To facilitate the cooperation process, the web-based interface automatically displayed the initial ideas to the respective other participants in the sub-groups.

1.4.2. Measurement of control variables

To account for the effects of problem complexity on idea generation performance in crowdsourcing (Afuah and Tucci, 2012, Dahlander et al. 2019, Felin and Zenger, 2014), we manipulated the *complexity* of the experimental task. A task is considered complex if it places high cognitive demands on the one performing it by having several interrelated and conflicting elements to satisfy (Campbell 1988). Hence, we increased the complexity of the bicycle parking problem by adding five dimensions that a potential solution would need to take into account (e.g., neighbors would like to reduce the noise and light from bicycle parking spaces).[6] All participants in the four main experimental groups (Table 2) were randomly assigned to the low vs. high-complexity description of the task (see Appendix 1 for the detailed descriptions).[7] We also control for *idea length* by using the word count of the final idea each participant submitted (in log.). Building on existing insights on the drivers of individuals' creative performance, we included covariates that potentially explain idea quality independently of our experimental treatments. Specifically, we measured participants' *self-efficacy* (Chen et al. 2001), *benefit* from a potential *bicycle* parking solution, and *bicycle experience* (adapted from Franke et al. 2014) in the pre-treatment survey, and *creativity* (adapted from Franke et al. 2014) in the post-treatment survey. To control for important demographic information, we measure *age, education,* and *gender* in the post-treatment survey. Except for self-efficacy, none of the control

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[6] We pre-tested the complexity measurement using a five-item scale adapted to our setting from Murthy et al. (2008). The 23 participants in the low complexity group (M=4.16, SD=1.48) and the 26 participants in the high complexity group (M=5.24, SD=0.85) perceived task complexity differently (t[49]=-3.18, p=0.00, two-tailed); as expected, the additional performance dimensions increased task complexity. A manipulation check in the main experiment also revealed significant differences: Participants who received the high-complexity task description (M=5.16, SD=1.15) reported a higher perceived task complexity than participants who generated ideas on the basis of the low-complexity task description (M=4.81, SD=1.31), t[294]=-2.43, p=0.02.

[7] There are no differences in participants' decision to revise their initial ideas between the low- and the high-complexity description of the task (chi2 (1, N=294)=0.042, p=0.838).

variables show any statistically significant differences between the main experimental groups, suggesting that our randomization worked (Table 3). The means of participants' self-efficacy are significantly lower in the low-competition groups. Items and reliabilities for all scale variables can be found in Appendix 2.

[Insert Table 3 about here]

1.4.3. Evaluation of outcome quality

Following prior research (e.g., Amabile et al. 2005, Poetz and Schreier 2012), we measure idea quality along three dimensions: (1) the *novelty* of the idea compared to existing solutions; (2) the *user benefit* as the importance of the idea to its end user, representing the user's perspective of whether the implemented idea will create value for its users; (3) the *feasibility* of the idea in terms of its ability to actually be implemented.

The performance of the ideas in terms of novelty and feasibility was assessed using industry experts (cf. Poetz and Schreier 2012) while the user benefit was assessed by potential users of the implemented idea (cf. Kornish and Ulrich 2014). The expert panel comprised two senior managers from firms producing bicycle parking infrastructure and a senior consultant in the area of cycling and public transport – all of them having a high understanding of cycling, bicycle traffic, and behavior of Danish cyclists. The three experts have extensive technical and market knowledge and were blind to the source of each idea. To ensure that the experts take sufficient time to carefully evaluate all 294 ideas, each rater received a remuneration of 6,000 DKK (about 950 USD).

The evaluation process followed a three-step procedure. In the first step, all experts were instructed on the rating criteria and individually rated the novelty and feasibility of 15 randomly selected ideas from pre-studies. Novelty was rated using the question "How novel is this idea compared to existing bicycle parking solutions at Danish universities?" on a scale ranging from "not novel at all" (1) to "very novel" (5). Feasibility was assessed with the question "How feasible is it to transform this idea into a solution for the market?" on a scale ranging from "not at all feasible" (1) to "very feasible" (5). After completing their individual evaluations online, the experts jointly discussed their ratings and partly resolved discrepancies during a workshop. In the second step, the experts were instructed to independently rate all ideas, so that each idea was evaluated by three experts. In the final third step, the experts jointly discussed the 50 ideas showing the highest standard deviations between the individual ratings, and were given the option to adapt their initial ratings if they wished to do so.

To construct our measures, we then averaged the ratings of the experts for each idea. Inter-rater agreement and consistency was assessed by calculating a two-way mixed effects model (LeBreton and Senter 2008). The ICC(3,3) for the mean rating, which can be interpreted as the reliability of the mean rating, is 0.80 for novelty and 0.76 for feasibility. Following the criteria for interpretation for ICC measures of Cicchetti (1994), this suggests adequate levels of agreement and reliability, thereby justifying aggregation of ratings across raters.

For evaluating the user benefit of an idea, we asked a panel of 13 users (i.e., cyclists, who ride their bike daily or at least several times a week and are thus regularly confronted with the bicycle parking problem) to rate whether they wanted an idea to be implemented or not. Raters were randomly distributed over all ideas such that each idea was rated by 6 users. To ensure that the raters take sufficient time to carefully evaluate all ideas, each rater received 340 DKK (about 50 USD). We transformed the answers into a count variable ranging from 0 to 6 (M=3.18, SD=1.67), indicating the number of raters who found an idea beneficial enough for it to be implemented.[8]

1.5. Results

1.5.1. Average outcome effects of individual-level coopetition

Figure 2 shows the average quality of ideas across our four main experimental groups with respect to novelty, user benefit and feasibility. It turns out that novelty is highest in the two low-competition groups, irrespective of whether cooperation was enabled or not ($p>0.10$). The highest user benefit is found in the cooperation group with a low level of competition ($p<0.05$) while the highest feasibility emerges in the no-cooperation condition with high competition ($p<0.05$).

[Insert Figure 2 about here]

Estimating the relationships between idea quality and individual-level coopetition, Table 4 shows OLS regression models in which the first column for each dependent variable displays the main

[8] A correlation table for all variables relevant to all experimental groups can be found in Appendix 3, while those only relevant to the coopetition groups can be found in Appendix 4.

effects of cooperation and competition[9] while the second column adds the interaction terms between the two variables as well as relevant control variables (individual characteristics of participants, task complexity and idea length). As Models 1 and 2 show, the average treatment effects of cooperation and competition on the novelty of ideas are not significant, neither is their interaction. Of the other explanatory variables, creativity and age are positively and significantly related to novelty, but the models in general fail to predict an idea's novelty well. Models 3 and 4 show that both cooperation and competition have a statistically significant positive effect on user benefit. Their interaction, however, is negative and significant, suggesting that cooperation leads to higher user benefit in the low-competition group than in the high-competition group. Lastly, the results in Models 5 and 6 suggest that cooperation has a negative and significant effect on feasibility while competition increases feasibility. This effect, however, disappears in Model 6, in which we do not find the interaction effect between cooperation and competition to be significant.

[Insert Table 4 about here]

1.5.2. Outcome effects of individual-level coopetition on top ideas

Since crowdsourcing processes usually aim at identifying the very best solutions for being further processed and implemented (Boudreau et al. 2011, Girotra et al. 2010, Terwiesch and Ulrich 2009), we explore how coopetition affects the top end of the distribution in each idea quality variable. To do so, we recoded ideas as "top-performing" with respect to novelty, user benefit and feasibility if they received the highest possible evaluation scores (i.e., when they received an average expert rating of five on the five-point rating scale for novelty and feasibility, and when six out of six users considered the idea's user benefit so high that they wanted it to be implemented). Figure 3 displays the expected and observed frequencies for the top ideas with respect to each dependent variable and subject to whether these ideas come from the high/low competition or from the cooperation/no-cooperation groups. We find similar patterns as in the previous regression analysis. However, while not statistically significant, we find more top ideas with respect to novelty than expected in the cooperation and high competition condition, suggesting that individual-level coopetition may actually propel idea novelty. Moreover, we find that more top ideas than expected with respect to user benefit

[9] A robustness check with equal observations in each experimental group shows that these regressions results are robust (see Appendix 1)

emerge when cooperation is enabled, irrespective of the level of competition. We observe the opposite pattern for top ideas with respect to their feasibility. Here, cooperation seems to hurt feasibility, and most of the highly feasible ideas emerge when competition is high, but cooperation is disabled. However, the differences between observed and expected frequencies are statistically insignificant.[10]

[Insert Figure 3 about here]

1.5.3. Investigating the coopetition process

Next, we explore the underlying knowledge exchange processes to better understand the dynamics that drive the outcome effects identified before. More specifically, we code and categorize the nature and quality of the knowledge exchanged between participants in the two coopetition groups. Then, we descriptively analyze how the different characteristics of the knowledge exchange process identified in this first step differ between the low and the high competition condition. Finally, we examine how the coopetition process characteristics relate to idea quality.

1.5.4. Content analysis of the knowledge exchange processes

During the idea generation process in the coopetition groups, participants were able to see others' initial ideas, comment on them and integrate knowledge from both, the ideas they saw and the comments they received on their own idea, in their final submission. We applied a qualitative content analysis to the text data generated. All coding and categorizing were carried out by one of the authors and a research assistant. To explore the type of knowledge exchanged and the process of knowledge recombination, we coded the changes participants made to their initial idea in the revision stage to examine whether or not the changes were motivated by the cooperation process. More specifically, we coded whether the revised ideas contain elements of one or more of the other ideas a participant saw at the beginning of the coopetition phase and whether the revised ideas contain elements of or address the feedback comments a participant received during the cooperation process. To illustrate this process, Table 5 provides coding examples.

[Insert Table 5 about here]

[10] We also conduct this analysis with different cut-off values (top novelty>=4.5, top user benefit>=5, and top feasibility>=4.5). The results are fully consistent.

Next, we draw on the literature on peer feedback (Gielen et al. 2010, Zhu et al. 2019) to develop a scheme for coding the type of knowledge participants received in the cooperation process. First, we coded all ideas as to whether or not they contained new problem-relevant knowledge in relation to the initial idea of the participant who saw the other ideas. Second, we coded all feedback comments that participants received on their initial idea using five categories: providing knowledge; asking questions; giving support; and voicing disapproval (see Table 6 for an overview and related coding examples). A feedback comment could fall into none, one, or multiple categories. In the case that a feedback comment did not fall into one of the previous categories, it was assigned the category "other". Interrater reliability prior to identification of disagreements, as measured by Krippendorff's alpha, was 0.88 on average for all coding categories. The remaining disagreements were resolved via discussions between the two raters.

[Insert Table 6 about here]

To complement the qualitative content analysis, we created a similarity measure of the ideas that participants saw in relation to their own idea following the approach outlined by Piezunka and Dahlander (2015). Moreover, we computed the similarity of the ideas after the participants had a chance to revise them. Before comparing the ideas, we removed non-alphabetical characters (e.g., punctuation, numbers, and blanks) and converted all words to lowercase. We lemmatized each word to its root form, which is the true dictionary form of any word, using WordNet. Furthermore, we removed stop words with little information content, such as "if" and "when". Then, following a "bag of words" approach, we transformed the remaining texts for the idea into word vectors, which we compared to one another. The similarity between ideas was computed using the Soft Cosine Measure (SCM), a method that allows us to assess the similarity between ideas in a meaningful way, even when they have no words in common (Sidorov et al. 2014). It applies a measure of similarity between words, which can be derived using word2vec vector embeddings of words (Mikolov et al. 2013). The word2vec algorithm builds on a neural network model to learn word associations from a large corpus of text. The similarity measure for each idea was computed as the average soft cosine similarity between an idea and the other ideas within the same group of ideas that were seen.

To analyze why participants in the cooperation groups decided to revise their initial ideas, respectively to explore whether, and if so, how any of the cooperation process variables influenced that decision, we compared initial and revised ideas to identify changes and then used the generated variable as our measure for a participant's revision of their idea. Moreover, in the post-treatment survey, participants could indicate which part of the cooperation process had influenced their revision most: "Seeing other ideas", "Giving feedback to other ideas", "Getting feedback", "The chance to win the contest", and "Other reasons [please specify]".

1.5.5. Overview of idea generation dynamics in individual-level coopetition

Figure 4 gives an overview of the different steps in the idea generation process in the coopetition groups and provides descriptive statistics for the low and high competition conditions.

[Insert Figure 4 about here]

On average, participants in the coopetition groups saw 4.0 in the low and 3.96 ideas in the high competition group (see Step 2).[11] Of those ideas, 3.8 ideas in the low competition group contained new knowledge compared to their own ideas, while only 3.3 did so in the high competition group. This means that participants in the low competition group saw significantly more ideas that were new compared to their own ideas ($p<0.05$).[12] Participants' average number of feedback comments on others' ideas was 3.6 in the low and 3.7 in the high competition group (see Step 3) ($p>0.10$). Furthermore, 77% of the participants in the low and 78% in the high competition group commented on all four ideas they saw, while only one participant in the low and none in the high competition group did not comment ($p>0.10$).

Exploring the comments that participants received (Step 4), the most common type of feedback received contained new knowledge. The average number of such comments received in the low competition group is 2.9 vs. 2.7 in the high competition group ($p>0.10$). The number of comments that asked questions is significantly lower in the low (0.29) than in the high competition group (0.93, $p<0.01$). Supporting comments were, on average, more frequently given in the low (2.4) compared to the high competition group (1.9, $p<0.01$). The low competition group received an average of 0.6 disapproving comments, while the high competition group received 0.5 disapproving comments ($p>0.10$). The remaining feedback comments that do not contain any explanatory value were more commonly received in the high (0.16) than in the low competition group (0.04, $p<0.01$). Hence,

[11] One participant in the high competition group did not submit an initial idea.
[12] This is a rather unexpected finding; thus, we elaborate on it in the *Notes* below Figure 4.

feedback given in the high competition group was more questioning and less supporting compared to the low competition group.

Participants reported that the most important reason for revising their ideas was the feedback they received, followed by the ideas they saw (Step 5). This finding does not differ between the low and high competition group ($p>0.10$). However, the third most important reason to revise the idea was the chance to win in the low and giving feedback in the high competition group. Our qualitative analysis that coded the cooperation processes aligns with these survey reports, showing that 37 out of 43 (86%) revised ideas incorporated feedback comments in the low and 61 out of 88 (69%) in the high competition group ($p<0.05$). A smaller share of revised ideas, i.e., 17 out of 43 (40%) in the low and 41 out of 88 (47%) in the high competition group, contained elements of the other ideas participants saw ($p>0.10$). This suggests that the incorporation of knowledge from ideas occurs less frequently than the incorporation of knowledge from feedback and is less important to participants in their decision of whether or not to revise their idea. Another observation is that the incorporation of elements from other ideas is not affected by the level of competition. In contrast to this, the low competition group incorporates feedback more often than the high competition group.

Moreover, we find that ideas actually become more similar to each other when participants cooperate. While our measure of idea similarity only changes from 0.23 for the initial ideas to 0.24 for the final ideas, the difference is statistically highly significant ($p<0.01$). We do not, however, observe significant differences between the low and high competition groups. This indicates that individual-level coopetition is associated with knowledge conversion, suggesting that more unusual ideas loose some of their uniqueness in the cooperation process.

In sum, our descriptive analysis shows that participants do cooperate under competition. Although they compete for one prize, they provide feedback to and absorb feedback from others. The knowledge that participants absorb is more often drawn from the feedback comments they received than from others' ideas they were able to see, although these ideas more often contained new knowledge.

1.5.6. Influence of cooperation process characteristics on innovative outcomes

The earlier results have shown that individual-level coopetition has no significant effect on novelty, a positive effect on user benefit, and a negative effect on feasibility. In this analysis, we explore how the characteristics of the knowledge exchange processes in the coopetition groups affect idea quality. Table 7 shows OLS regressions that display the relationships between the coopetition process variables and each dependent variable. Models 1 and 2 show that the number of other ideas a participant saw that contained new knowledge relates positively to an idea's novelty. Similarly, received feedback that contained new knowledge is positively associated with idea novelty while feedback that asks questions is negatively related to novelty. In that sense, providing new knowledge may have led participants to recombine that knowledge with their own idea and consequently to achieve higher novelty. In contrast, asking (critical) questions may have taken out the most novel features of an idea. Models 3 and 4 show that questioning feedback is positively related to user benefit. We find no other significant relationship with one of the cooperation process characteristics. Here, asking (critical) questions may have led participants to change their idea in a way that better reflects user demands. Finally, Models 5 and 6 show significant associations with three cooperation process variables. We find a negative relationship with feedback that contained new knowledge but positive relationships with questioning and supporting feedback. This result indicates that providing additional knowledge can be excessive, adding too many features to an idea that undermine its feasibility. In contrast, questioning and supportive feedback may have led participants to reconsider in which way their ideas could be adapted to become more feasible. In all models, we find that the level of competition does not play a role for idea quality.

[Insert Table 7 about here]

Next, we seek to investigate the characteristics of the cooperation process that the top ideas with respect to novelty, user benefit and feasibility were subject to. Table 8 shows the expected and observed frequencies of top ideas by knowledge exchange process. We convert the knowledge exchange process variables into dummy variables by splitting them below and above the scale mid-point, i.e., participants could have been exposed to few or many types of knowledge exchange processes. A number of significant results emerges. Ideas that scored highest with respect to novelty had particularly received feedback comments that contained knowledge. Top ideas regarding user benefit had received mostly supportive comments while top ideas regarding feasibility had received fewer feedback comments that contained knowledge as well as comments that were asking questions. These results are consistent with the findings presented in Table 7 regarding an idea's novelty, but they also highlight differences for user benefit and feasibility. For user benefit, top ideas benefit from support instead of questions. For feasibility, top ideas benefit from fewer comments containing knowledge (as in Table 7) but they also benefit from fewer questions which had shown a positive relationship with feasibility in Table 7. Moreover, we do not find supportive comments to be important for top feasible ideas. However, our results also need to be interpreted with care as several cells have no or very few observations.

[Insert Table 8 about here]

It is important to note that the results on the relationship between knowledge exchange processes and idea quality cannot be considered as causal as we cannot fully rule out the endogeneity of feedback comments given to particular ideas. Better initial ideas may attract different feedback and the effect of feedback on idea quality would thus be hard to establish. We seek to address this concern in two ways, building on the assumption that the initial ideas in both the cooperation and no-cooperation groups have equal distributions of idea quality. First, we test whether ideas that the participants decided not to revise (i.e., the final submitted idea is the same as the initial idea) differ in idea quality between the cooperation and no-cooperation groups. We do not find this to be the case for the three dimensions of idea quality. Second, for the cooperation groups (n=147), we coded whether the final ideas (i.e., the ideas submitted after the participants had the opportunity to cooperate) changed in their idea quality. Despite a revision, many ideas did not change in their idea quality (out of 147 ideas, 98 did not change regarding their novelty, 87 regarding user benefit and 101 regarding feasibility). Then, we test whether ideas that the participants in the no-cooperation group decided not to revise differ in idea quality from the ideas in the cooperation group that the participants decided to revise but that did not change in idea quality. Again, we find the differences to be statistically insignificant. In sum, these analyses provide no evidence that the best initial ideas might have received better feedback which in turn might have led to higher idea quality.

1.6. Discussion

How does coopetition in innovation contests affect innovative outcomes? Prior research has typically focused on a "winner-takes-all" incentive structure in which individuals cannot cooperate (Körpeoğlu and Cho 2018, Terwiesch and Xu 2008) and treated competition and cooperation as two separate dimensions for explaining innovative outcomes (Afuah and Tucci, 2012). Combining competition and cooperation by allowing contestants to exchange knowledge and ideas, however, fundamentally changes the nature of the contest, creating a situation of individual-level coopetition. Drawing on prior literature related to the separate effects of cooperation and competition on the generation of innovative solutions provides inconclusive evidence. Having an opportunity to cooperate allows participants to be cognitively stimulated, either by the ideas they see (Dugosh et al. 2000, Riedl and Seidel 2018) or the feedback that they receive (Fleming et al. 2007, Kogut and Zander 1992), providing a basis for knowledge recombination. But seeing other ideas may also lead to fixation effects that constrain creativity (Hofstetter et al. 2021) while feedback often disimproves the best ideas (Wooten and Ulrich 2017). More substantially, allowing participants to cooperate may compromise the potential performance effects of competition (Boudreau et al. 2011) as the contestants do not have a direct incentive to share their knowledge because others can free-ride on it and increase their own winning chances (Wasko and Faraj 2005, Landkammer and Sassenberg 2016). Moreover, contestants may withhold knowledge or even sabotage others by offering ill-intentioned advice (Harbring and Irlenbusch 2011). As a result, the effect of individual-level coopetition on innovative outcomes in innovation contests has remained unclear.

In this paper, we address our research question in two steps that seek to carefully map the coopetition process in order to reconcile the conflicting evidence. Hence, we adopt a question-driven approach that accounts for the complexities of the coopetition process and the different facets of innovation contest outcomes, more specifically the sub-dimensions of innovative outcomes. Here, we focus on an idea's novelty, user benefit, and feasibility which have been characterized as the three most important outcome dimensions of creative idea generation processes (Blohm et al. 2013, Zhu et al. 2019). Our findings show that individual-level coopetition has different effects on the dimensions of idea quality. Letting contest participants cooperate has no effect on novelty while it has a positive effect on user benefit and a negative effect on feasibility. This suggests that cooperation between the contestants involves trade-offs as it does not unequivocally benefit the generation of innovative solutions in search processes that are organized as a contest. Instead, it might also be a hampering factor. This finding qualifies prior research on the benefits of cooperation (Dugosh et al. 2000, Riedl and Seidel 2018, Majchrzak and Malhotra 2020) and may explain part of the conflicting results when the dimensions of outcome quality remain unaccounted for.

In that sense, our findings for an idea's novelty are suggestive of two competing effects. While the cooperation process provides individuals with additional knowledge that they can recombine with their own in order to create a more novel solution, cooperation may also iron out the ideas that really stand out as particularly novel. The positive effect on user benefit suggest that the cooperation process helps participants to reconsider and improve their solution with respect to its usefulness and value, pointing to the importance of user integration in generation of innovative solutions. The negative effect on feasibility may be due to an extension of the idea generation phase in the cooperation groups in our experimental set-up. Research on different phases in idea generation processes suggests that feasibility concerns are commonly addressed once the elaboration phase of the ideation journey is reached, i.e., only after a core idea has been generated (Perry-Smith and Mannucci 2017). In our context, seeing others' ideas and getting feedback likely extends the idea generation phase and may lead individuals to overload their solutions with features that decrease overall feasibility. In turn, participants from the no-cooperation groups move on to the elaboration phase, where ideas are systematically evaluated and improved.

Moreover, we find that a higher level of competition in the contest tends to have a positive effect on both user benefit and feasibility, and we also find a negative (even though weakly significant) interaction effect of cooperation and the level of competition on user benefit. While competition has been argued to affect the effort that contestants exert (Boudreau et al. 2011, Terwiesch and Xu 2008), which in turn influences individual performance (Moldovanu and Sela 2006), competition fails to show a significant effect on the novelty of an idea. This finding may indicate that an idea's novelty – in contrast to user benefit and feasibility – is a feature which can hardly be influenced just by increasing the effort one is willing to make in a contest. In turn, the negative interaction effect of cooperation and the level of competition on user benefit suggests that higher competition actually decreases the benefits that cooperation has on coming up with an idea with high user benefit. Under high competition, participants seem to withhold some of their inputs to the cooperation process, limiting the ability of others to benefit from cooperation. This finding is corroborated when considering the top-rated ideas with respect to user benefit. Here, we find that cooperation is most helpful for spawning such ideas when the level of competition is low. Hence, our results challenge literature emphasizing the benefits of organizing innovation as a contest (e.g., Boudreau et al. 2011), as competition interacts with cooperation in a way that undermines the benefits of both cooperation and competition for ideas with high user benefit. In sum, while the first step of the analysis establishes the baseline for the effects of individual-level coopetition on idea quality, we need to move to the results of the second step to better understand the mechanisms at work.

In this step, we provide an in-depth account of the cooperation process that unfolds between the contestants and therefore limit the sample to individuals who were allowed to cooperate in the innovation contest. Coding the exchange between participants reveals that they cooperate in a multitude of different ways. Not only do they disclose ideas from which others can draw inspiration, but they also provide an extensive range of feedback comments to each other. Our analysis reveals that the feedback may provide knowledge but may also stimulate individuals to reconsider their ideas when they are questioned about them or when they receive support or disapproval. This feedback, followed in importance by the chance to see others' ideas, turns out to be the driving force behind participants' decision to revise their ideas. In fact, most of the revised ideas also contained elements of the received feedback. The uptake of feedback is also significantly higher with increasing levels of competition, suggesting that participants are even more motivated to improve their ideas. The type of feedback that participants receive also tends to differ between groups interacting under low or high competitive conditions, respectively. While those in a high competition condition received more questions on their ideas, they also received much less support from others. Hence, we provide evidence on varied forms of cooperation between contest participants who still compete against each other for the same prize.

Turning to the relationship between the cooperation process and the three dimensions of innovative outcome, our findings highlight that the participants' decision to revise their ideas as a consequence of the ideas they had seen and the feedback they had gathered not always benefits idea quality. Again, we observe marked differences between novelty, user benefit and feasibility that help to better understand the outcome effects found in our first analysis. When contestants cooperate, more novel ideas are associated with having received more knowledge – either through having seen others' ideas that contained new knowledge or through feedback comments providing new knowledge – but also with having received less questions about one's idea. This finding provides evidence for the importance of knowledge recombination for creating highly novel ideas and it cautions against an all too inquisitive process that may instill uncertainty about one's idea, leading participants to draft a less controversial but also less novel idea. Contrary to an idea's novelty, its user benefit is positively related to questioning feedback. Here, the feedback may lead contestants to consider aspects that are brought up by others – often times users themselves – to make the idea more comprehensive and overall beneficial for a broad audience. Finally, our results for an idea's feasibility suggest that ideas can get overburdened quickly if individuals integrate elements from feedback that offers new knowledge, leading to "feature fatigue". Instead, feasibility benefits from questioning and supportive feedback comments that helps participants to focus on the most important elements of their idea and its potential to be implemented. Overall, our findings paint a nuanced picture of the effects of individual-level coopetition in innovation contests. Figure 5 summarizes the effects and relationships investigated in the two empirical studies.

[Insert Figure 5 about here]

The findings from our two empirical studies advance prior research in at least two ways. First, innovation contests have been characterized as an emerging organizational form that has gained considerable attention in the literature (e.g., Afuah and Tucci 2012, Boudreau et al. 2011, Jeppesen and Lakhani 2010, Riedl and Seidel 2018), yet we lack a theory of individual-level coopetition that would help elucidate our understanding of the effects of cooperation on idea quality when individuals compete with each other for a prize. Compared to other forms of organization for innovation, such as R&D departments, innovation contests constitute loosely coupled organizational forms (Dahlander and Wallin 2006, Franke et al. 2013) through which firms can obtain highly innovative solutions (Poetz and Schreier 2012, Terwiesch and Ulrich 2009). They are considerably less stable and reliable than other forms of organization for the generation of innovation because individuals self-select into temporary and decentralized problem-solving activities with very low entry and exit barriers (Dahlander and Frederiksen 2012). These features, combined with the cooperative and competitive dynamics that unfold in the contest, lead to a differentiated picture with respect to the resulting quality of innovative outcomes. In that sense, our research challenges both literature on the benefits of competitive innovation contests (e.g., Boudreau et al. 2011, Terwiesch and Xu 2008) and literature on community-based crowdsourcing that strongly advocates for the benefits of cooperation (e.g., Füller et al. 2014, Majchrzak and Malhotra 2020). Individual-level coopetition may both spur and hamper innovative outcomes, and the effects depend largely on how the innovation contest enables individuals to cooperate.

Second, our model of individual-level coopetition in innovation contests that is based on the two empirical studies extends prior coopetition research which is largely focused on the firm level

(Cassiman et al. 2009, Gnyawali and Park 2011, Ritala and Hurmelinna-Laukkanen 2013) or the level of units, departments or teams within organizations (An et al. 2020, Baumann et al. 2019, Ghobadi and D'Ambra 2012, Luo et al. 2006, Tsai 2002). Our research shows that a coopetition perspective can be fruitfully applied to the individual level in an organization's search for innovative solutions to innovation problems. In fact, connecting with (distant) sources of innovation outside a firm's boundaries has long been characterized as essential for a firm's innovation performance (e.g., Chesbrough 2003, Afuah and Tucci 2012) but the individual-level underpinnings of such initiatives have remained under-researched and consequently under-theorized. Ignoring the individual level despite the prevalence of coopetition dynamics in new forms of engaging with individuals outside the firms' boundaries may therefore impede a better understanding of when and how innovation contests provide firms with valuable solutions for being adopted in their innovation activities. Hence, our research addresses a gap in extant coopetition literature that has so far been silent about individual-level outcomes that are important for an organization's innovation performance. In addition, our findings open up for theorizing in other contexts in which individuals compete but also cooperate, for example, when individual employees who cooperate in daily task performance compete for promotions or resources (Banks et al. 2021, DeVaro 2006), or when researchers who cooperate in academic activities compete for publications, tenure, and grants (Gerosa 2001, Leydesdorff et al. 2014).

1.7. Conclusion

We find that individual-level coopetition in innovation contests has differential effects on dimensions of innovative outcome. Allowing contestants to cooperate fundamentally alters the nature of the innovation contest with substantive implications on the novelty, user benefit and feasibility of the ideas generated. Our results not only contribute to extant literature on innovation contests as well as coopetition but also hold obvious management insights. In that sense, contest organizers need to be aware of the dynamics that unfold when participants may cooperate by seeing each other's ideas or sharing knowledge. Consequently, contest organizers need to prioritize the dimension of idea quality that they place particular importance on when allowing for cooperation. While cooperation itself is, on average, unrelated to an idea's novelty, cooperation should be enabled when an idea's user benefit is a key concern but disabled when its feasibility is important. Moreover, contest organizers need to be aware that cooperation increases the similarity of submitted ideas, leading to a convergence of knowledge that might iron out the most unusual and innovative ideas.

Further, our results suggest that – when cooperation is enabled – contest organizers might want to encourage specific types of feedback to increase a specific dimension of idea quality. Novelty, for example, may increase when contestants are encouraged to provide each other new knowledge inputs that serve as a basis for knowledge recombination. Building on the work on constrained versus "un-cuffed" crowds that highlights the benefits of the latter (Majchrzak and Malhotra 2020), it may be promising to investigate how organizations can utilize guidelines on knowledge sharing – e.g., by calling for the provision of knowledge and asking questions – to support the desired dimension of idea quality instead of fully unleashing the crowd.

Overall, our findings document that individuals are eager and willing to cooperate, even though they compete for the same prize. Cooperative behavior is also largely unaffected by the degree of competition among the participants. Given the contest in which individuals compete against each other, we show that the degree of competition interacts with the effect of cooperation on idea quality only to a limited extent. Contest organizers may therefore harness the benefits of higher competition on participants' effort and still enable opportunities for cooperation.

1.7.1. Limitations and future research

Although our research provides a careful analysis of the individual-level coopetition dynamics that unfold in innovation contests, it is not without limitations which, in turn, offer opportunities for future research. First, the use of a laboratory experiment may raise common concerns about the external validity of our results. Participants recruited into the experiment that was run at a university lab may not be representative of other populations. At the same time, however, anecdotal evidence suggests that participants of firm-hosted innovation contests typically consist of younger, technology-savvy individuals that we believe our experimental groups represent fairly well. Nevertheless, it would be desirable to repeat our experiment in the field, i.e., in a real-world innovation contest sponsored by a firm that seeks solutions to an innovation problem.

Second, our experiment only allowed for one-time interactions between participants in the cooperation group. More specifically, it did not allow participants to react to feedback comments and further discuss these issues with the feedback-giving participant or ask for clarification. Moreover, participants did not engage in further rounds of the contest in which they could have built up a relationship with others. Research on firm or unit-level coopetition typically assumes a relationship that goes beyond a single interaction that our study on individual-level coopetition is unable to mimic. However, our results indicate that a single interaction already suffices in order to observe the effects of cooperation on idea quality. Future research may explicitly account for innovation contests that run over several rounds and allow participants build up relationships characterized by trust (Jarvenpaa and Majchrzak 2010) or reciprocity considerations (Kathan et al. 2015).

Third, we cannot fully rule out the endogeneity of feedback comments given to particular ideas. Better initial ideas may attract different feedback and the effect of feedback on idea quality would thus be hard to establish. Our research provides a number of consistency checks suggesting that differences in idea quality are actually due to the cooperation process. Moreover, we cannot rule out that some feedback comments that we had coded as providing knowledge, supportive or disapproving might have been provided with a strategic intention to sabotage, i.e., to mislead or discourage, the other participants (e.g., Charness et al. 2014, Harbring and Irlenbusch 2011). Based on the qualitative insights provided by the participants in the survey instrument, we have no evidence to believe that this behavior was a widespread phenomenon. Nevertheless, future research may be dedicated to better understand the relationship between initial ideas and the type of feedback provided, taking potentially misleading behavior of participants into account.

Finally, participants in our study were not able to form teams and to submit ideas jointly because we sought to isolate the effect of cooperation under competitive conditions and joint submission would have effectively stalled competition. Nevertheless, future research could build on our insights and study the consequences of team formation (vs. individual submission) in innovation contests. Building on insights from Jin et al. (2021) and Riedl and Woolley (2017) who study teams jointly working on a solution, it would be desirable to get a better understanding of how the option to submit as a team alters perceptions of competition and idea quality. While enabling team submissions might increase fruitful cooperation within the team, competition with other individuals or teams might limit cooperation with team outsiders and, thus, be potentially detrimental to overall idea quality, as less knowledge is shared within the crowd.

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1.9. Tables and figures

Tables

Table 2: Number of participants in each experimental group

Competition Treatment	Cooperation Treatment: No-cooperation	Cooperation Treatment: Cooperation	Total
Low	55	48	103
High	92	99	191
Total	147	147	294

Table 3: Study 1 sample descriptive statistics and randomization checks

	No cooperation				**Cooperation**				**Equal distribution across experimental groups**	
	Low competition		**High competition**		**Low competition**		**High competition**			
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Test[a]	p-value
Self-efficacy	5.282	0.819	5.553	0.637	5.315	0.714	5.538	0.811	K.-W.	0.047
Bicycle benefit	3.900	1.241	3.875	1.400	3.646	1.194	3.838	1.414	K.-W.	0.733
Bicycle experience	5.073	1.372	4.978	1.684	4.917	1.569	4.980	1.591	K.-W.	0.984
Creativity	3.664	0.640	3.766	0.735	3.797	0.736	3.889	0.787	K.-W.	0.187
Age	25.709	5.682	24.565	3.728	24.167	3.379	25.061	4.483	K.-W.	0.699
Education (1=Master's)	0.327	0.474	0.304	0.463	0.333	0.476	0.202	0.404	Chi-2	0.208
Gender (1=Female)	0.455	0.503	0.446	0.500	0.396	0.494	0.434	0.498	Chi-2	0.935
Observations	55		92		48		99			

Notes.
[a] All continuous variables are not normally distributed, hence we use non-parametric Kruskal-Wallis equality-of-populations rank tests (K.-W.). For the categorical variable we use Pearson's chi-squared tests (Chi-2).

Table 4: OLS regression results

	Novelty		User benefit		Feasibility	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Variables	OLS	OLS	OLS	OLS	OLS	OLS
Cooperation (0=No/1=Yes)	0.027	0.060	0.428*	0.915**	-0.288*	-0.417*
	(0.124)	(0.210)	(0.194)	(0.330)	(0.122)	(0.205)
Level of Competition (0=Low/1=High)	-0.147	-0.135	0.160	0.542+	0.325*	0.242
	(0.130)	(0.181)	(0.204)	(0.285)	(0.128)	(0.177)
Cooperation x Level of Competition		-0.100		-0.703+		0.270
		(0.261)		(0.412)		(0.256)
Task complexity		0.049		-0.300		0.329**
		(0.123)		(0.194)		(0.121)
Idea length (log.)		-0.130		0.078		0.037
		(0.107)		(0.169)		(0.105)
Self-efficacy		-0.003		-0.033		-0.070
		(0.086)		(0.135)		(0.084)
Bicycle benefit		-0.020		0.091		0.050
		(0.047)		(0.073)		(0.046)
Bicycle expertise		-0.028		0.063		0.034
		(0.040)		(0.063)		(0.039)
Creativity		0.232*		-0.183		-0.125
		(0.492)		(0.776)		(0.482)
Age (log.)		-0.370*		0.291		0.458**
		(0.174)		(0.273)		(0.170)
Education (1=Master's)		0.139		-0.282		-0.018
		(0.128)		(0.201)		(0.125)
Gender (1=Female)		-0.100		-0.703+		0.270
		(0.261)		(0.412)		(0.256)
Constant	3.223***	-0.950	2.859***	5.915*	3.522***	7.240***
	(0.120)	(1.784)	(0.187)	(2.810)	(0.117)	(1.745)
Observations	294	294	294	294	294	294
R-squared	0.004	0.066	0.019	0.068	0.038	0.102
F-statistic	0.652	1.665	2.827	1.720	5.748	2.658
Prob > F	0.522	0.074	0.0618	0.062	0.004	0.002

Notes. Standard errors in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001.

Table 5: Coding examples for (not) incorporating knowledge from the cooperation process

Cooperation process step	Exemplary participant ideas and comments	
(A) Example for not incorporating ideas seen and comments received (participant from the low competition group)		
Initial idea	My idea is to optimized the efficiency of the bicycles racks. On the campus the racks should be organize to maximize the capacity of bicycles - Furthermore it would help with elevated bicycle racks, which will optimized the amount of bicycles per m^2. In that way we should have a efficint and sheap solution	
Other ideas seen	Construct an underground bike parking lot which you can access from the lecture rooms on the ground floor using a student ID. Entrances and exists also have to be to the outside in different corners of the campus. This ensure no theft and the bikes are covered from rain and bad weather. To use the space more efficiently, the bikes can be stored in bike racks with two levels (like the ones at Hovedbanegården). This will not take [idea not finished due to time restriction]	A basement parking, where you bring your bike down to be parked in the basement of the buildings on campus that have the available space for it. Following a bit the logic of parking in big public spaces (f.ex. shopping malls), letters and numbers are assigned to each parking spot, so finding your bike at the end of the day becomes easier for you. By having it sheltered inside a basement, the bikes remain protected of weather conditions and theft possibilities. At the same time, they are parked on campus (inside the buildings) so it remains convenient for students and staff. Because the parking spots are underground, no historically relevant sites or the creating of more available space in the surface is needed.
Comments received	You can add a roof over the bike racks to protect them from bad weather. Maybe you can have a system such that you can only access a bike rack with a student/staff ID to prevent theft.	How would you organize the rack differently? Maybe you can make that more clear on your proposal? How would you deal with the existing problem of lack of space?
Revised idea	A cheap suggestion for a better solution. We need to calculated the best organized way for the racks to create as much capacity for bikes within the given space at the faculty. Then we need to upgrade the racks with a second level (elevation) - in that way we will have an efficient solution given the space we have. It's cheap and it will create more capacity	
(B) Example for incorporating ideas seen and feedback comments received (participant from the high competition group) [emphasis in ideas and comments added to highlight the incorporated aspects]		
Initial idea	I would suggest to replace some of the existing bicycle racks currently present at universities with more modern ones that maximize the space available. I would suggest racks that have 2 lines one above each other so as to use the vertical space too. They will be closed on the top so as to prevent damage from rain. In order for students to access there parking spots I would implement an annual membership for a small price.	
Other ideas seen	In order to save space for bike parking a good solution would be to **introduce carousels for bikes**. Carousels are space efficient, of low price and could be introduced very close to the university building. The carousel for bikes would be a way to park bikes close to each other on small space and spin the carousel to pick up your bike.	Students want to have parking **closer to lecture rooms**, we should therefore already have parking where we have parking. I know that several other countries have build parking in more levels - so that you can have parking on top of each other.
Comments received	How would the membership secure the bikes from **theft**?	**I don't think that students would want to pay any annual membership** for being able to park in their university, I also don't find it fair that they should.
Revised idea	I would suggest to replace some of the existing bicycle racks currently present at universities with more modern ones that maximize the space available. These new bike **carousel** will be placed **next to universities lectures rooms** so as to be fast and easily accessible by students. They will be closed on the top so as to prevent damage from rain and snow. In order for students to access there parking spots and to limit the risk of **theft**, the carousel could only be activated with a student annual membership. These bike memberships will be annual and **free of charge for students**.	

Table 6: Feedback categories and coding examples

Category	Description	Example
Knowledge	The comment contains new problem-relevant knowledge compared to the given initial idea	You can add a roof over the bike racks to protect them from bad weather. Maybe you can have a system such that you can only access a bike rack with a student/staff ID to prevent theft.
Asking questions	The comment asks a question	How would we hang bikes up in the ceiling at the university? Wouldn't that be dangerous? And wouldn't the wall storage need a lot of space and could be also dangerous? Or would it be meant for a basement?
Support	The comment offers support/motivation	The station is a great idea, actually.
Disapproval	The comment expresses disapproval	People will just stop using a bike or park that far away from the lecture rooms. It wouldn't solve a thing.
Other	The comment does not fall under any of the previous categories	In this case the students will park way longer from their

Table 7: Regressing idea quality on the coopetition process variables

	Novelty		User benefit		Feasibility	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
VARIABLES	OLS	OLS	OLS	OLS	OLS	OLS
Other ideas: New knowledge	0.204+	0.230+	-0.218	-0.256	-0.012	0.129
	(0.122)	(0.133)	(0.201)	(0.218)	(0.128)	(0.137)
Feedback received: Knowledge	0.244*	0.206*	0.038	0.086	-0.305**	-0.236*
	(0.094)	(0.097)	(0.155)	(0.158)	(0.099)	(0.099)
Feedback received: Asking questions	-0.147+	-0.176*	0.384**	0.347*	0.166*	0.291**
	(0.078)	(0.085)	(0.129)	(0.140)	(0.082)	(0.088)
Feedback received: Supporting	-0.104	-0.111	0.091	0.133	0.269**	0.209+
	(0.097)	(0.104)	(0.160)	(0.169)	(0.102)	(0.106)
Feedback received: Disapproving	0.050	0.067	-0.200	-0.281	0.110	0.115
	(0.104)	(0.108)	(0.172)	(0.177)	(0.110)	(0.111)
Competition (0=Low/1=High)	-0.066	-0.006	-0.152	-0.280	0.031	-0.002
	(0.229)	(0.231)	(0.379)	(0.378)	(0.242)	(0.237)
Task complexity		-0.064		-0.176		0.515*
		(0.213)		(0.349)		(0.218)
Idea length (log.)		-0.051		-0.468+		0.545**
		(0.169)		(0.276)		(0.173)
Self-efficacy		0.308+		-0.113		-0.244
		(0.184)		(0.301)		(0.188)
Bicycle benefit		-0.033		0.049		-0.001
		(0.112)		(0.183)		(0.115)
Bicycle expertise		-0.011		0.028		0.053
		(0.064)		(0.104)		(0.065)
Creativity		-0.034		0.132		0.041
		(0.054)		(0.088)		(0.055)
Age (log.)		0.254*		-0.277		-0.088
		(0.114)		(0.187)		(0.117)
Education (1=Master's)		0.953		-0.640		-0.442
		(0.698)		(1.143)		(0.716)
Gender (1=Female)		-0.247		0.370		0.379
		(0.252)		(0.412)		(0.258)
Constant		-0.035		-0.641*		-0.088
		(0.176)		(0.288)		(0.181)
Observations	2.114***	-2.796	3.323***	6.577	3.763***	4.723+
R-squared	(0.554)	(2.527)	(0.915)	(4.137)	(0.583)	(2.591)
F-statistic	146	146	146	146	146	146
Prob > F	0.117	0.194	0.100	0.192	0.114	0.233

Notes. Standard errors in parenthesis. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001.

Table 8: Expected and observed frequencies for the top ideas related to each dependent variable across knowledge exchange processes

			Other ideas: New knowledge			**Feedback received: New knowledge**			**Feedback received: Questions**			**Feedback received : Support**			**Feedback received: Disapproval**		
			<2 comments	>=2 comments	p-value	<2 comments	>=2 comments	p-value	<2 comments	>=2 comments	p-value	<2 comments	>=2 comments	p-value	<2 comments	>=2 comments	p-value
Top Novelty	No	Observed	1	129	0.619	16	114	0.041	103	27	0.431	41	89	0.757	117	13	0.564
		Expected	0.884	129.116		14.15	115.85		101.701	28.299		41.565	88.435		117.619	12.381	
	Yes	Observed	0	17		0	17		12	5		6	11		16	1	
		Expected	0.116	16.884		1.85	15.15		13.299	3.701		5.435	11.565		15.381	1.619	
Top User Benefit	No	Observed	1	130	0.631	15	116	0.500	102	29	0.753	46	85	0.008	118	13	0.619
		Expected	0.891	130.109		14.259	116.741		102.483	28.517		41.884	89.116		118.524	12.476	
	Yes	Observed	0	16		1	15		13	3		1	15		15	1	
		Expected	0.109	15.891		1.741	14.259		12.517	3.483		5.116	10.884		14.476	1.524	
Top Feasibility	No	Observed	118	13	0.679	12	123	0.027	103	32	0.013	45	90	0.211	123	12	0.417
		Expected	118.524	12.476		14.694	120.306		105.612	29.388		43.163	91.837		122.143	12.857	
	Yes	Observed	15	1		4	8		12	0		2	10		10	2	
		Expected	14.476	1.524		1.306	10.694		9.388	2.612		3.837	8.163		10.857	1.143	

Figures

Figure 1: Overview of the experimental process

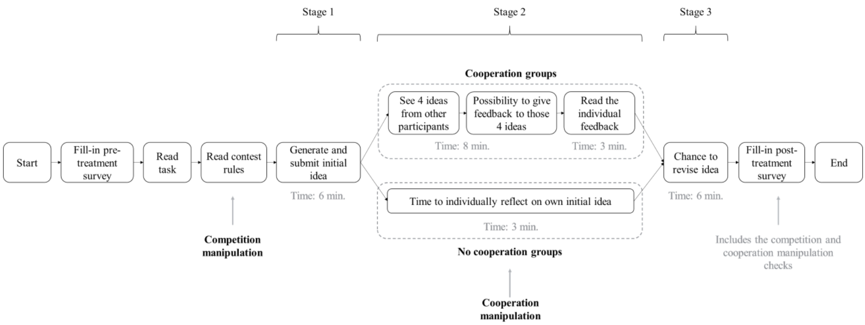
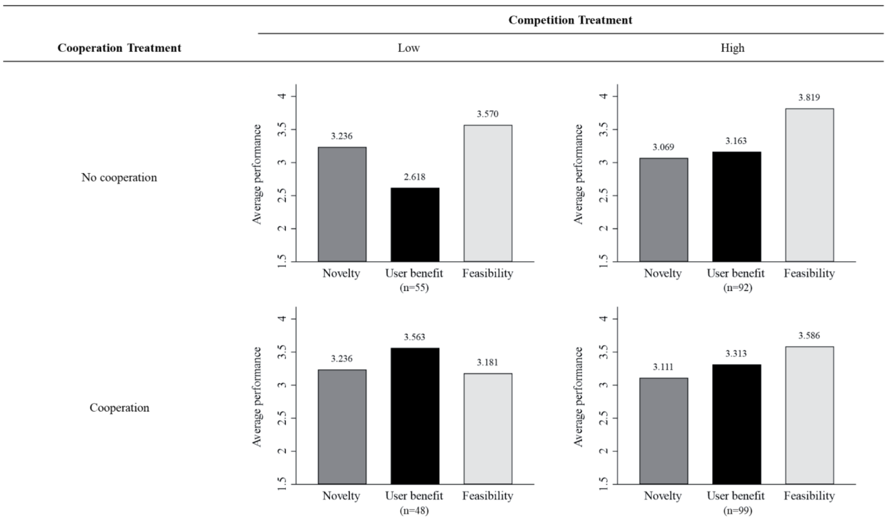
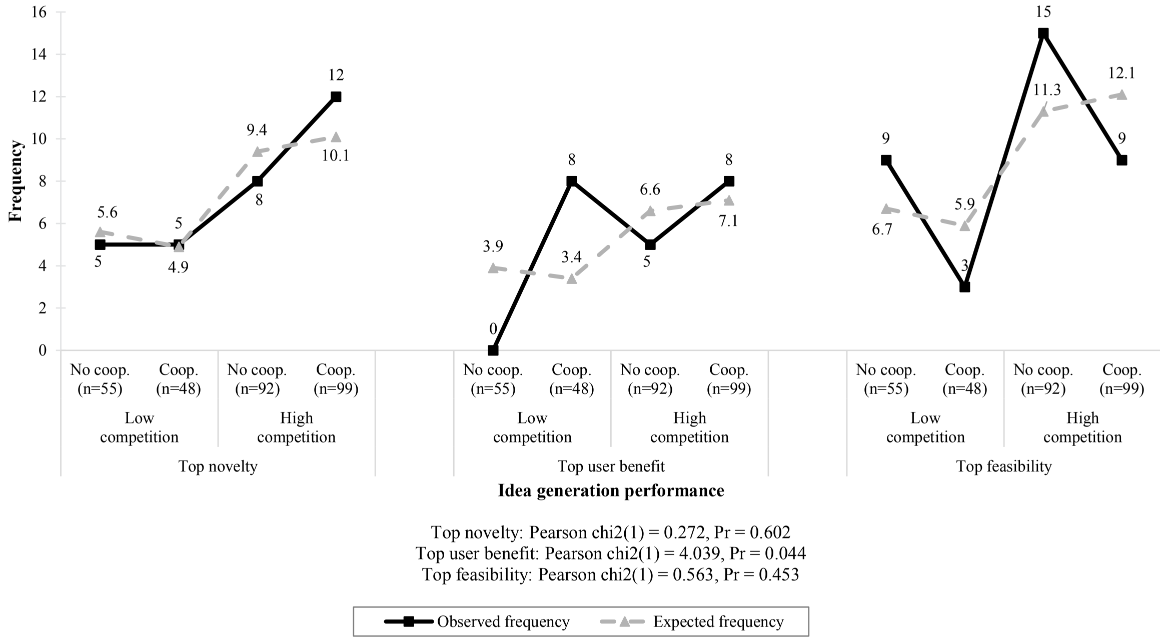


Figure 2: Average idea quality by cooperation and competitive condition



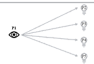
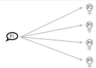
Notes. All idea quality dimensions (i.e., novelty, user benefit, and feasibility) are not normally distributed, hence we use non-parametric Kruskal-Wallis equality-of-populations rank tests to test for differences between the mean values of each idea quality dimension by experimental group. For novelty: chi2(3) = 1.619, Pr = 0.655; user benefit: chi2(3) = 8.508, Pr = 0.037; feasibility: chi2(3) = 9.484, Pr = 0.024.

Figure 3: Expected and observed frequencies for the top ideas related to each dependent variable across cooperation and competition groups



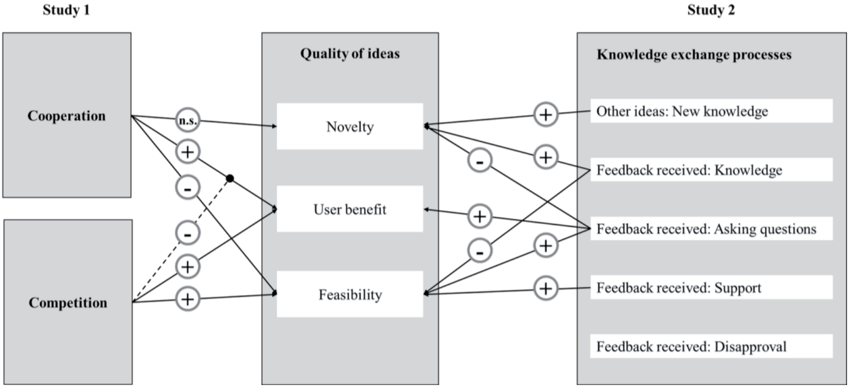
Notes. The figure only presents the expected and observed frequencies for the top ideas and omits the frequencies for the ideas that are among the “rest” to allow for easier interpretability. However, the reported ChiSquare tests do include those observations and allow a statistical comparison between the groups and top ideas per dependent variable (top vs. rest).

Figure 4: An overview of the idea generation dynamics in the coopetition groups

Idea generation steps		Variables		Descriptive statistics: Low competition	Descriptive statistics: High competition	Equal distribution across experimental groups: Test[a]	Equal distribution across experimental groups: p-value
Step 1: Generate ideas		Average number of *words* per *initial idea*		99.50 words	102.08 words	T-test	0.733
Step 2: See other ideas		Average number of other *ideas a participant saw (max. 4 possible)*		4.00 ideas	3.96 ideas	T-test	0.160
		Average number of *other ideas* a participant saw that *contained new knowledge* [b]		3.81 ideas	3.34 ideas	Mann-W.	0.000
Step 3: Option to comment on others' ideas		Average *number* of *feedback comments a* participant *gave (max. 4 possible)*		3.56 comments	3.68 comments	Mann-W.	0.776
		Average *number of words* per *feedback comment* a participant gave		25.76 words	28.42 words	Mann-W.	0.284
Step 4: Receive comments - if any were given		Average *number* of *feedback comments* a participant *received (max. 4 possible)* [c]		3.56 comments	3.68 comments	Mann-W.	0.256
		Average number of *feedback comments* a participant received that *contained:*	Knowledge	2.92 comments	2.70 comments	Mann-W.	0.330
			Question	0.29 comments	0.93 comments	Mann-W.	0.000
			Support	2.35 comments	1.87 comments	T-test	0.014
			Disapproval	0.58 comments	0.47 comments	Mann-W.	0.400
			Other	0.04 comments	0.16 comments	Mann-W.	0.009
Step 5: Chance to revise ideas		Number of participants that revised their idea [d]		43 out of 48 participants (90%)	88 out of 99 participants (89%)	Chi-squared	0.899
		Number of revised ideas that contained elements of:	Seen ideas	17 out of 43 revised ideas (40%)	41 out of 88 revised ideas (47%)	Chi-squared	0.445
			Received feedback	37 out of 43 revised ideas (86%)	61 out of 88 revised ideas (69%)	Chi-squared	0.038
		Average number of *words* per *revised idea*		130.10 words	135.41 words	Mann-W.	0.735
		Initial idea similarity in cooperation clusters		0.23	0.23	Mann-W.	0.927
		Final idea similarity in cooperation clusters		0.24	0.24	Mann-W.	0.876
		Average *rank* that participants, who revised their idea, gave the item in respect to its *influence on their decision to revise* their idea:	Seeing other ideas	2.37	2.59	T-test	0.498
			Giving feedback	3.49	3.22	T-test	0.168
			Receiving feedback	1.84	1.82	Mann-W.	0.764
			Chance to win	3.16	3.30	Mann-W.	0.738

Notes. [a] In case that a variable is not normally distributed, we use the non-parametric Mann-Whitney U test instead of a two-sided t-test. For ordinal variables we use Pearson's chi-squared tests (Chi-2). [b] This difference can be due to three reasons: i) The competition treatment affected the diversity of the initial ideas generated, ii) this is simply a random and unexplainable difference that occurs although our experimental randomization was successful, or iii) because the sample sizes between experiment groups are different. While we can do little about i) and ii), we can address iii). Hence, as a robustness check for this difference we randomly drop observations, so that all experimental groups have an equal number of observations (the lowest number is 48 in the low competition group). Results are similar to the ones we find in the full sample: The average number of other ideas a participant saw that contained new knowledge in the low competition group (M=4, SD=0) is higher than in the high competition group (M=3.96, SD=0.29). The two-sided test shows a non-significant difference (t(94)=1.43, p=0.16), but the one-sided test is significant at the 10% level (p=0.08). Hence, we have reason to believe that the difference is due to reason i) or ii). [c] The average number of feedback comments a participant gave and received is more significant in Step 4 because the allocation of feedback comments to the cooperation partner can differ in distribution. For example, 114 (20) participants gave 4 (3) feedback comments, but 103 (37) participants received 4 (3) feedback comments. The total number of feedback comments given is equal to the total number of feedback comments received (i.e., 535 comments). [d] The sample size in the low competition group is lower than in the high competition group due to Covid restrictions in the lab experiment participant recruiting process for the low competition group. Hence, the number of participants in the cooperation and low (high) competition group is 48 (99).

Figure 5: Drivers of innovative outcomes in individual-level coopetition



1.10. Appendix

Appendix 1: Task description

Low complexity

It can be very difficult to find bicycle parking close to a university's lecture buildings. Although more than 20.000 students are enrolled and about 2.000 faculty and staff are employed, only about 750 bicycle parking spaces are available. Anyone who has tried to find a parking space at 08:30 AM knows this is a real problem. Space restrictions and the listed historical sites on campus constitute a principal obstacle to adding substantial numbers of additional bicycle racks. Suppose you are a member of a student organization that is researching this problem for officials of the university. Your task is to suggest a solution to the deciding committee.

The committee has also given you information about the interests of the students, who would like to park their bicycles close to the lecture rooms secure from theft and damage.

On the following pages, you will receive more detailed instructions for completing this task.

High complexity

It can be very difficult to find bicycle parking close to a university's lecture buildings. Although more than 20.000 students are enrolled and about 2.000 faculty and staff are employed, only about 750 bicycle parking spaces are available. Anyone who has tried to find a parking space at 08:30 AM knows this is a real problem. Space restrictions and the listed historical sites on campus constitute a principal obstacle to adding substantial numbers of additional bicycle racks. Suppose you are a member of a student organization that is researching this problem for officials of the university. Your task is to suggest a solution to the deciding committee.

The committee has also given you information about the interests of the main stakeholders (students, university administration, city officials, and neighbors). Students would like to park their bicycles close to the lecture rooms secure from theft and damage. University administrators would like to avoid randomly parked bikes blocking the entrances, and neighbors would like to reduce the noise and light from bicycle parking spaces. City officials would like to make sure that any expansion of the bicycle parking does not cut into green areas, the historical sites, and car parking spaces nearby. On top of that, due to recent budget cuts the proposed solutions should be implementable with minimal financial resources.

On the following pages, you will receive more detailed instructions for completing this task.

Appendix 2: Constructs, items, scales, and reliabilities

Construct	**Items**	**Cronbach's Alpha**	**Source**
Bicycle benefit	1. I have already experienced bicycle parking problems. 2. Bicycle parking problems are limiting my bicycle usage.	-	Adapted from Franke et al. (2014)
Bicycle experience	1. I would consider myself an expert in terms of my knowledge of cycling mobility.	-	Adapted from Franke et al. (2014)
Creativity [a]	1. I enjoy spending time looking beyond the initial view of the problem. 2. I enjoy working on ill-defined, novel problems. 3. I enjoy stretching my imagination to produce many ideas. 4. I like to work with unique ideas.	0.78	Franke et al. (2014)
Self-efficacy	1. I will be able to achieve most of the goals that I have set for myself. 2. When facing difficult tasks, I am certain that I will accomplish them. 3. In general, I think that I can obtain outcomes that are important to me. 4. I believe I can succeed at most any endeavor to which I set my mind. 5. I will be able to successfully overcome many challenges. 6. I am confident that I can perform effectively on many different tasks. 7. Compared to other people, I can do most tasks very well. 8. Even when things are tough, I can perform quite well.	0.85	Chen et al. (2001)
Perceived task complexity [b]	1. Was no challenge at all - - - - - - - Was a challenge 2. Required almost no effort - - - - - - - Required high effort 3. Required no analytical skills - - - - - - - Required high analytical skills 4. Was cognitively undemanding - - - - - - - Was cognitively demanding 5. Was simple - - - - - - - Was complex	0.88	Adapted from Murthy et al. (2008), based on Campbell (1988), Schroder et al. (1967), and Wood (1986)

Notes: Unless otherwise indicated, the 7-point Likert scale ranges from 1=strongly disagree, 2=disagree, 3=somewhat disagree, 4=neither agree or disagree, 5=somewhat agree, 6=agree, to 7=strongly agree. [a] Creativity was measured on a 5-point scale ranging from 1 =Not at all accurate to 5=Very accurate. [b] Perceived task complexity is used as our manipulation check for task complexity only.

Appendix 3: Correlation table for variables used in Study 1

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1) Novelty	1.00																	
(2) User benefit	-0.36^{***}	1.00																
(3) Feasibility	-0.43^{***}	0.14^{*}	1.00															
(4) Top novelty	0.59^{***}	-0.15^{*}	-0.21^{***}	1.00														
(5) Top user benefit	-0.11^{+}	0.47^{***}	-0.04	-0.09	1.00													
(6) Top feasibility	-0.21^{***}	0.12^{*}	0.50^{***}	-0.13^{*}	-0.10^{+}	1.00												
(7) Cooperation	0.01	0.13^{*}	-0.13^{*}	0.04	0.15^{*}	-0.12^{*}	1.00											
(8) Competition	-0.07	0.05	0.14^{*}	0.01	-0.02	0.01	0.05	1.00										
(9) Task complexity	0.03	-0.10^{+}	0.15^{**}	-0.04	-0.06	0.06	-0.01	0.02	1.00									
(10) Idea length (log.)	-0.06	0.03	0.02	-0.04	0.04	-0.03	0.06	0.07	0.02	1.00								
(11) Self-efficacy	0.00	-0.00	-0.02	-0.00	-0.04	-0.08	0.01	0.16^{**}	0.01	0.08	1.00							
(12) Bicycle benefit	-0.01	0.06	0.05	0.01	0.01	0.06	-0.04	0.03	-0.08	0.01	0.12^{*}	1.00						
(13) Bicycle expertise	-0.04	0.05	0.04	0.00	0.05	0.14^{*}	-0.02	-0.01	-0.05	-0.04	0.10^{+}	-0.03	1.00					
(14) Creativity	0.15^{**}	-0.07	-0.08	0.03	-0.12^{*}	-0.12^{*}	0.09	0.07	0.02	0.15^{**}	0.24^{***}	0.09	-0.04	1.00				
(15) Age (log.)	0.13^{*}	-0.08	-0.05	0.14^{*}	0.04	-0.06	-0.02	-0.01	0.05	-0.20^{***}	-0.01	0.08	-0.05	0.12^{*}	1.00			
(16) Education	0.00	-0.01	0.08	-0.03	0.06	0.02	-0.08	-0.08	0.06	-0.12^{*}	0.05	0.08	-0.03	0.17^{**}	0.59^{***}	1.00		
(17) Gender	0.06	-0.08	0.01	-0.05	-0.06	0.09	-0.03	0.01	0.01	0.12^{*}	0.04	0.05	0.17^{**}	0.15^{*}	-0.05	-0.01	1.00	
(18) Revision decision	0.00	-0.00	0.06	0.07	0.01	-0.03	0.21^{***}	0.01	-0.02	0.27^{***}	0.02	0.08	-0.02	0.05	-0.06	-0.07	-0.03	1.00

Notes. Observations: 294; $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Appendix 4: Correlation table for variables relevant to the cooperation group

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1) Novelty	1.00																	
(2) User benefit	-0.36^{***}	1.00																
(3) Feasibility	-0.45^{***}	0.20^{*}	1.00															
(4) Competition (0=Low/1=High)	-0.06	-0.07	0.18^{*}	1.00														
(5) Other ideas: New knowledge	0.17^{*}	-0.11	-0.03	-0.33^{***}	1.00													
(6) Feedback received: Knowledge	0.25^{**}	0.02	-0.24^{**}	-0.10	0.05	1.00												
(7) Feedback received: Asking questions	0.00	0.03	0.10	0.32^{***}	-0.06	0.30^{***}	1.00											
(8) Feedback received: Supporting	-0.18^{*}	0.27^{***}	0.14	-0.20^{*}	-0.04	-0.10	-0.21^{*}	1.00										
(9) Feedback received: Disapproving	0.11	-0.17^{*}	0.01	-0.06	0.11	0.03	-0.13	-0.21^{*}	1.00									
(10) Task complexity	0.01	-0.17^{*}	0.20^{*}	0.01	-0.02	0.03	0.06	-0.19^{*}	-0.05	1.00								
(11) Idea length (log.)	0.11	0.03	-0.06	0.01	0.04	0.05	0.14	0.27^{**}	-0.27^{***}	-0.00	1.00							
(12) Self-efficacy	0.01	-0.03	0.02	0.14^{+}	-0.13	0.03	0.04	-0.06	-0.01	0.09	0.05	1.00						
(13) Bicycle benefit	-0.04	0.04	0.07	0.06	-0.11	-0.03	0.03	-0.03	-0.09	-0.01	-0.02	0.18^{*}	1.00					
(14) Bicycle expertise	-0.10	0.10	0.10	0.02	0.01	-0.12	0.03	0.04	-0.03	-0.01	-0.00	0.05	0.03	1.00				
(15) Creativity	0.20^{*}	-0.14^{+}	-0.07	0.06	-0.13	0.07	-0.00	0.03	0.03	0.04	0.17^{*}	0.24^{**}	0.03	-0.03	1.00			
(16) Age (log.)	0.12	-0.07	-0.02	0.10	-0.17^{*}	0.11	0.06	-0.26^{**}	0.09	0.03	-0.15^{+}	0.05	0.10	0.02	0.11	1.00		
(17) Education	-0.01	0.01	0.06	-0.14^{+}	-0.13	-0.01	-0.03	-0.14^{+}	0.07	0.08	-0.13	0.02	0.09	0.00	0.08	0.60^{***}	1.00	
(18) Gender	0.02	-0.15^{+}	-0.04	0.03	0.06	0.09	0.09	0.04	-0.13	0.01	0.14^{+}	0.09	-0.02	0.19^{*}	0.15^{+}	0.04	0.06	1.00

Notes. $^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Appendix 5: Robustness check for the regression results (equal observations in each experimental group)

	Novelty		**User benefit**		**Feasibility**	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Variables	OLS	OLS	OLS	OLS	OLS	OLS
Cooperation (0=No/1=Yes)	0.038	-0.008	0.375	0.967**	-0.351*	-0.388+
	(0.150)	(0.214)	(0.251)	(0.357)	(0.152)	(0.217)
Competition (0=Low/1=High)	-0.142	-0.216	0.063	0.734*	0.392*	0.375+
	(0.150)	(0.216)	(0.251)	(0.361)	(0.152)	(0.219)
Cooperation x Competition		0.066		-1.125*		0.103
		(0.303)		(0.507)		(0.307)
Task complexity		0.125		-0.366		0.293+
		(0.151)		(0.252)		(0.153)
Idea length (log.)		-0.224+		0.077		0.137
		(0.127)		(0.212)		(0.128)
Self-efficacy		0.040		-0.058		-0.101
		(0.110)		(0.184)		(0.111)
Bicycle benefit		-0.050		0.072		0.024
		(0.058)		(0.097)		(0.059)
Bicycle expertise		-0.035		0.069		0.032
		(0.050)		(0.083)		(0.050)
Creativity		0.189		-0.255		-0.139
		(0.115)		(0.193)		(0.117)
Age (log.)		1.096+		-1.021		-1.221*
		(0.602)		(1.006)		(0.610)
Education (1=Master's)		-0.359+		0.145		0.483*
		(0.208)		(0.347)		(0.211)
Gender (1=Female)		0.004		-0.370		-0.041
		(0.155)		(0.259)		(0.157)
Constant	3.252***	0.323	2.875***	6.416+	3.516***	7.326**
	(0.130)	(2.260)	(0.217)	(3.777)	(0.132)	(2.291)
Observations	192	192	192	192	192	192
R-squared	0.005	0.079	0.012	0.090	0.059	0.136
F-statistic	0.484	1.272	1.147	1.483	5.963	2.342
Prob > F	0.617	0.239	0.320	0.134	0.003	0.008

Notes. Standard errors in parenthesis. + p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001.

Chapter 2 – The Influence of Competitive Reward Structures on Cooperative Behavior in Innovation Contests: Experimental Evidence

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2.1. Abstract

Many platforms hosting innovation contests allow their participants to cooperate by sharing ideas and knowledge and many participants take advantage of this opportunity, questioning common beliefs that competitive rewards lead individuals to withhold knowledge and impair the progress of others while cooperative rewards promote knowledge sharing. In this paper, we build on social interdependence theory to analyze how and when competitive reward structures influence the likelihood that contestants cooperate. Using two experimental vignette studies, we find that – while competitive reward structures negatively impact an individual's likelihood to cooperate – many contest participants still cooperate with each other. Next, we apply a multi-stage configurational approach to identify, categorize and specify attributes that influence the individuals' decision to cooperate and then explore their relative importance. We find that the decision to cooperate is determined by bundles of attributes. While the fear of misappropriation plays a prominent role in all bundles irrespective of the degree of competition, it is intrinsic motivation of individuals that is important when competition is high and extrinsic motivation when competition is low.

Keywords: innovation contests, cooperation, competition, social interdependence theory, configurational approach

2.2. Introduction

Innovation contests have gained a prominent role in firms' activities to access external knowledge that they can integrate into their innovation process (e.g., Boudreau et al. 2011, Körpeoğlu and Cho 2018, Terwiesch and Xu 2008). Based on the idea of broadcast search to reach more distant sources of innovation (Afuah and Tucci 2012), problems are posted to potential problem solvers who compete for the best solution which is then rewarded by the problem holder or seeker organization with a prize (Liu et al. 2014). At the same time, contest platforms typically allow individual problem solvers to cooperate. They can exchange knowledge by sharing their ideas, commenting on others' ideas, and incorporating ideas and comments from others into their own solution before they submit.

Cooperating by exchanging knowledge in innovation contests with others represents a public good dilemma (Cabrera and Cabrera 2002). Public goods are shared resources from which group members can benefit without depleting them, irrespective of whether they contributed to their production (Olson 1965). However, since everybody can benefit from the shared knowledge as it is not restricted to contributors only, individuals may free-ride, i.e., use the resource without contributing (Sweeney 1973). Moreover, sharing knowledge is associated with cost, even though modest, and may imply individuals lose their competitive edge (Cabrera and Cabrera 2002). While innovation contests assign individuals to a competitive reward structure, social interdependence theory of cooperation and competition would lead us to believe that cooperative reward structures are important to motivate individuals to share their knowledge and experience (Deutsch 1949, Tjosvold 1989). Social interdependence exists as the group of individuals is linked by competitive social interaction in which the individuals' goal achievements are negatively correlated because only one or a few can obtain the prize (Beersma et al. 2003, Johnson 2003, Johnson and Johnson 1989).

Yet, the simple notion that cooperative rewards promote knowledge sharing and mutually supportive behavior in groups while competitive rewards lead individuals to keep valuable information proprietary and to harm the progress of others (Beersma et al. 2003) seems incorrect in light of widespread evidence that individuals do cooperate in innovation contests (Riedl and Seidel 2018). For example, contestants heavily use the discussion board on Kaggle.com, an online contest platform for data scientists, statisticians, and machine learning experts, on which they can, but do not have to share their coding scripts, allowing others to read, discuss, vote for, and integrate them into their own submission. Prior research suggests that individuals may be motivated to cooperate because they seek to gain higher status or reputation in a crowd of problem solvers, because the contest may be about finding a pro-social, not-for-profit solution, because learning from each other may increase the winning chances, or because individuals derive pleasure and fun from engaging in the contest (e.g., Füller et al. 2014, Jin et al. 2021, Kathan et al. 2015, Majchrzak and Malhotra 2020). These insights indicate that the relationship between competitive reward structures and cooperation might be influenced by a set of interrelated factors concerning the problem solver's own attributes, the attributes of other participants in the contest, and the attributes of the contest itself. But it is precisely these interrelations that complicate the identification of the effect of competition on cooperation in innovation contests. In that sense, understanding the conditions under which competitive reward structures lead individuals to cooperate (or not) is critical for understanding the boundary conditions of social interdependence theory and its theoretical predictions (Kistruck et al. 2016).

Hence, in this paper, we ask two related research questions: how do competitive reward structures in innovation contests influence the likelihood that individuals will choose to cooperate, and what are the conditions under which competition affects the cooperative behavior of contestants? By answering these questions, we extend social interdependence theory by integrating insights from the literature on coopetition. Defined as a relationship between two or more actors that simultaneously engage in cooperation and competition (Bengtsson and Kock 2014), coopetition has been predominantly viewed as an arrangement on the firm level that enables sharing knowledge and other types of resources to contribute to an organization's innovation performance (Cassiman et al. 2009, Gnyawali and Park 2011, Ritala and Hurmelinna-Laukkanen 2013). But coopetition is also a pervasive phenomenon on other levels. On the unit level, for example, organizational units in multiunit organizations typically compete for internal resources as well as status and rewards and, at the same time, seek to learn from each other and exchange knowledge (Tsai 2002). On the individual level, academic researchers compete for different "prizes" associated with discovery (e.g., a publication), but still share information during the research process (Haeussler et al. 2014). Despite the relevance of innovation contests for firms' innovation performance (Jeppesen and Lakhani 2010), prior literature has yet to view cooperation in innovation contests as coopetition on the individual level, offering an opportunity for theorizing in extension of social interdependence theory.

Our research proceeds in two steps. First, we study the role of different competitive reward structures on the likelihood of individuals to cooperate in an innovation contest. Here, we are not only interested in different levels of competition but also in the distinction between competitive and non-competitive structures. Competition typically results from several factors, including evaluation, reward, and a win-lose aspect that is characteristic to competitive situations (Amabile et al. 1996; Brown et al. 1998, Murayama and Elliot 2012). We focus on structural competition that an individual is subject to in a given situation and manipulate different levels of the prize money. Consistent with social interdependence theory, we argue that more competitive reward structures (higher levels of the prize money) lead individuals to refrain from cooperating in innovation contests.

Second, we are interested how different configurations in an innovation contest regarding the problem solvers' own attributes, the attributes of other contest participants, and the attributes of the contest influence the likelihood that individual contestants will choose to cooperate, given different levels of competition. Configurational approaches have been argued to facilitate insights into the equifinality of different combinations of attributes or characteristics (Fiss 2007), i.e., we seek to understand which configurations would lead individuals to cooperate under non-competitive, lowly competitive and highly competitive reward structures of the innovation contest.

Empirically, we conduct two studies. In Study 1, we implement an experimental vignette study (3 x 1 between-subject design) to test our hypotheses related to the effect of different competitive reward structures on individuals' likelihood to cooperate in innovation contests, i.e., exchange their ideas and knowledge with other participants. Based on a sample of 405 individuals, we find a negative and statistically significant effect of competitive reward structures on individuals' willingness to exchange their idea and knowledge in innovation contests. We also find that this negative effect is more pronounced for individuals' likelihood to share their ideas and knowledge with other contestants than their likelihood to absorb ideas and knowledge from others.

In Study 2, we apply a configurational approach to investigate which inter-related attributes have most influence on the complex decision-making of individual contest participants to cooperate under competitive conditions. We use a multi-step approach to identify and categorize potentially relevant drivers of cooperation under competitive conditions by means of a review of existing literature and interviews with real-world participants in innovation contests that enable cooperation among contestants (n=15). The outcome of this factor exploration feeds into an adaptive choice-based conjoint (ACBC) study and a related cluster ensemble analysis with 562 study participants. The results indicate that it is not a single attribute, but a bundle of attributes that matter in the decision-making process to exchange ideas and knowledge with other participants in an innovation contest. Two clusters emerge in each competitive condition: The first cluster is dominated by the fear of misappropriation, and this cluster can be found under all competitive conditions. The second cluster is a combination of intrinsic motivation resulting from fun and learning (in the highly competitive condition) and extrinsic motivation resulting from obtaining rewards for sharing ideas and knowledge (in the no- and lowly-competitive condition) with other factors such as the helpfulness of the knowledge provided by other participants or the complexity of the problem to be solved.

We contribute to the extant literature in at least two ways. First, despite the theoretical interest in and practical relevance of innovation contests as an emerging organizational form (e.g., Afuah and Tucci 2012, Boudreau et al. 2011, Jeppesen and Lakhani 2010, Riedl and Seidel 2018), the decision of individuals to cooperate in such contests has remained undertheorized. Social interdependence theory typically focuses on an organizational context, in which team members employed by the organization are assigned to either competitive or cooperative reward structures (Deutsch 1949, Tjosvold 1989). However, innovation contests are considerably less stable and reliable than other forms of organization for the generation of innovation such as, for example, teams of R&D employees (Franke et al. 2013). Hence, understanding when individuals outside organizational boundaries – who do not form teams but constitute a group linked by competitive social interaction – engage in coopetition and how competition interacts with configurations of innovation contests extends social interdependence theory (Beersma et al. 2003, Johnson and Johnson 1989, Johnson 2003) and, more broadly, advances research on the management and organization of innovation (Argyres and Silverman 2004, Dahlander and Frederiksen 2012). Moreover, our research informs the practical implementation of innovation contests regarding the factors that increase or decrease cooperation among contestants which allows seeker organizations to fine-tune the balance between competition and cooperation for solving innovation challenges.

Second, we advance a model of individual-level coopetition in innovation contests that is informed by social interdependence theory and rooted in a configurational analysis. While prior coopetition research has typically been focused on the firm level (Cassiman et al. 2009, Gnyawali and Park 2011, Ritala and Hurmelinna-Laukkanen 2013) or the unit level within the boundaries of the organization (An et al. 2020, Baumann et al. 2019, Tsai 2002), our research fills a void in extant coopetition literature by extending coopetition research with an understanding of how competitive dynamics in new forms of engaging with individuals outside the firms' boundaries facilitate innovation cooperation. Our research offers insights on the conditions under which individuals cooperate with each other although they compete for the same prize which can help managers to better understand what it takes to encourage or discourage cooperation.

2.3. Cooperation in innovation contests

Broadcasting innovation problems to a large crowd of potential solvers has frequently been described as a way how firms can engage in distant search and tap into distributed sources of knowledge and skills beyond firm boundaries (e.g., Afuah and Tucci 2012, Jeppesen and Lakhani 2010). Such innovation contests seek to identify the best ideas and to incorporate them subsequently into the firm's innovation process (Girotra et al. 2010, Terwiesch and Ulrich 2009). In fact, Poetz and Schreier (2012) document that ideas and solutions generated in innovation contests can complement or even outperform those developed internally on dimensions such as novelty and user benefit, and are equally good in terms of feasibility when focusing on the top ideas.

Challenges to be solved in an innovation contest can be complex, requiring the individuals to exert more effort and to address different features of the task environment (Cross et al. 2001, Nakatsu et al. 2014) which in turn decreases chances of challenges to get solved (Afuah and Tucci 2012, Dahlander et al. 2019). To address these difficulties in solving more complex problems, contestants are oftentimes allowed to cooperate with each other, for example by means of a discussion board where contestants have the opportunity to share knowledge such as coding scripts as in the case of Kaggle.com. Contestants can also discuss their ideas with each other, vote, and further develop them prior to submission. Similarly, 80% of all the contests listed on the contest platform 99designs.com have cooperative features that allow participants to see and engage with other ideas (Hofstetter et al. 2021).

Our understanding of cooperation rests on the idea that individuals exchange resources such as knowledge, discuss problems, or provide assistance, support and encouragement (Argyle 1991, Tjosvold 1988). Hence, cooperation in innovation contests is defined as an interactive and relational behavior between individuals to achieve their individual goals (Bullinger et al. 2010, Chen et al. 1998, Milton and Westphal 2005). The interaction between the contestants does not have to be symmetrical nor beneficial for the individual (Milton and Westphal 2005, Thomson and Perry 2006). Because individuals still compete for the same prize, our conceptualization of cooperation is distinct from collaboration in innovation contests in which individuals can form teams or work in communities to achieve a joint outcome (Thomson and Perry 2006). Kaggle.com is a case in point as it offers participants to continue competing individually or to form a team working on a joint solution (Jin et al., 2021). Hence, we focus on a situation in which participants can, but do not have to cooperate and still compete individually for the same prize, i.e., we study individual-level coopetition in the context of generating innovation.

The benefits of cooperation rely on the idea of recombining existing knowledge in novel ways (Kogut and Zander 1992, Nelson and Winter 1982, Schumpeter 1934). In particular, they are the result of novel combinations of perspectives and approaches people are exposed to in interactions with others (Perry-Smith 2006, Perry-Smith and Shalley 2003). Enabling participants to share and recombine their private knowledge creates great creative potential. Knowledge sharing allows participants to solve increasingly complex and ambiguous problems (Cross et al. 2001). This potential is based on the participants' diversity of backgrounds and experiences that allows participants to experiment with a larger set of knowledge recombinations (Fleming et al. 2007, Savino et al. 2017).

2.4. Study 1: The effect of competitive reward structures on cooperation in innovation contests

2.4.1. Theory and hypotheses

Innovation contests are competitive because solvers compete for the same prize awarded to the best solution. More generally, competition exists where two or more parties strive for a common goal that cannot be shared (Stigler 2017). Prior research finds that increased competition in innovation contests typically increases participants' effort (Moldovanu and Sela 2006, Terwiesch and Xu 2008), especially by the highly skilled (Körpeoğlu and Cho 2018), and this increase in effort leads to better quality of the idea. Boudreau et al. (2011) highlight that higher competition can particularly nurture the generation of the desired extreme value outcomes. These outcomes are of special interest in innovation contests, as only a limited number of the best ideas can be implemented by the contest organizer (Girotra et al. 2010, Terwiesch and Ulrich 2009).

Three distinct ways of conceptualizing interpersonal competition have emerged (Brown et al. 1998, Murayama and Elliot 2012) that focus on the characteristics of the person (trait competitiveness), the perceived situation (perceived environmental competitiveness), and the actual situation (structural competition). Innovation contests set the degree of structural competition while the cognitive construal of the contest's competitive nature defines an individual's perceived competition (Murayama and Elliot 2012). In other words, an individual's assessment of the respective winning chances for the prize is expressed through perceived competition (Deutsch 1949, Johnson and Johnson 1989). Structural competition and perceived competition are related situation-dependent concepts, as both competition characteristics address the impact that the subjective perception of the situation has on the behavior of an individual (Ames and Archer 1988, Deutsch 1949, Murayama and Elliot 2012). One way to set the degree of structural competition relates to the amount of monetary incentives offered. Generally speaking, higher levels of monetary incentives are related to or increase perceived competition (Huang et al. 2012). There is some evidence suggesting that this effect is, at least partly, mediated by higher prizes attracting more participants in open-entry contests (Liu et al. 2014). Similarly, average effort levels decrease for higher incentives (given a rise in perceived competition), but for the highest-skilled participants effort increases considerably (Boudreau et al. 2016, Körpeoğlu and Cho 2018).

Social interdependence theory argues that an individual's subjective perception of competition influences cooperative behavior (Deutsch 1949). Lower perceived competition increases an individual's propensity for promotive interactions with competitors (i.e., supporting and encouraging others), while higher perceived competition fosters interactions that are potentially obstructing and discouraging other participants (Johnson 2003). Higher perceived competition leads individuals to doubt their chances of winning and thus their inclination to help others in the contest decreases (e.g., Baer et al. 2010). Once participants share their privately held knowledge, it becomes a public good and they can no longer claim its exclusive value (Cabrera and Cabrera 2002). In fact, Foege et al. (2019) find that problem solvers experience value expropriation upon revealing their knowledge, which makes them very cautious in sharing their knowledge in the first place. Hence, sharing knowledge can have adverse effects for the individual's own competitive advantage and these effects likely increase when competition increases (Levy et al. 2003, Luo et al. 2006).

Cabrera and Cabrera (2002) highlight that cooperating by sharing knowledge represents a public good dilemma that the contestants face: Most participants would prefer the opportunity to draw from others' knowledge and insights to save time and effort. Yet, they are reluctant to contribute themselves in the fear that others will free-ride on their contributions. Moreover, sharing knowledge involves real cost as it consumes valuable time that could be spent on working on one's own solution. Increasing competition thus increases the personal vulnerability that contributing individuals assume, so that they may feel that hoarding instead of sharing is a better strategy (Cabrera and Cabrera 2002). Similarly, competitive settings suppress trust (Costa et al. 2018, Swab and Johnson 2019). Trust is an individual's willingness to be vulnerable to the actions of other individuals (Mayer et al. 1995), implying that an individual needs to take a certain amount of risk when engaging with others (Johnson-George and Swap 1982). Prior research shows that a decline in trust indeed reduces knowledge sharing (Chiu et al. 2006) because lower trust increases the risks associated with the interaction to undermine the individual's competitive advantage.

Then again, literature on the selective revealing of innovation-relevant knowledge highlights that selectively disclosing knowledge can function as a mechanism to initiate cooperative behavior of others even under conditions of high partner uncertainty and high search costs and when known partners are unwilling to cooperate (Alexy et al. 2013, Foege et al. 2019). While contestants may be willing to contribute knowledge to motivate others to do the same when the level of competition is low, it becomes more unlikely with increasing levels of competition. In sum, our first hypothesis reads:

Hypothesis 1 (H1): There is a negative effect of competition on individuals' willingness to exchange ideas and knowledge with competitors.

Our understanding of cooperation in innovation contests has so far been based on knowledge exchange processes between a focal participant and the other individuals in the contest. However, this process can also be differentiated into an individual's willingness to share ideas and knowledge and his or her inclination to absorb ideas and knowledge that were shared by other participants. As an extension to our first hypothesis, we suggest that increasing levels of competition will cause participants to refrain from behavior that does not directly relate to their own performance (Connelly et al. 2014) because they decrease their own competitive advantage (Levy et al. 2003, Luo et al. 2006). In that sense, increasing competition likely reduces the willingness of individuals to share their ideas and knowledge. Conversely, we argue that increasing competition leads individuals to absorb ideas and knowledge that were shared by others and, in that sense, free-ride on others' contributions. Our second hypothesis thus reads:

Hypothesis 2a (H2a): There is a negative effect of competition on individuals' willingness to share their ideas and knowledge with competitors.

Hypothesis 2b (H2b): There is a positive effect of competition on individuals' willingness to absorb ideas and knowledge from competitors.

2.4.2. Methods

We use an experimental vignette study to test our hypotheses. More specifically, we examine the effect of different competitive reward structures on individuals' likelihood to cooperate in an experimental scenario task. As part of this task, study participants were provided with a randomly assigned description of a realistic idea generation challenge with varying competitive reward structures (non-competitive, lowly competitive and highly competitive), i.e., *the scenario*, and asked to decide whether or not to exchange their ideas and knowledge with competing participants. The no-, low- and high-competition treatments were operationalized by means of different levels of the prize money a winner could obtain.

2.4.2.1. Participants

We recruited 452 participants from the online platform Prolific Academic. In recent years, Prolific Academic has been an increasingly used participant source for online experiments (e.g., Montealegre and Jimenez-Leal 2019, Mount et al. 2021) as they produce higher-quality data and are more diverse than participants from MTurk (Peer et al. 2017). In our study, we compensated participants with USD 2.34 for completing a task that, on average, took them 14 minutes to complete (including the post-treatment survey).

As response quality of inattentive participants can lead to meaningless data in online experiments (Berinsky et al. 2016, Curran 2016), we include a comprehension check (Mount et al. 2021), use a relative completion speed index (Leiner 2019), and filter for meaningless text data entries. The comprehension check asked participants to recall the number of prizes and the amount of prize money that were mentioned in the scenario (i.e., we checked for the recollection of our competition treatment; see Appendix 6 for the question and items). The relative completion speed index is embedded in the survey tool we used (SoSci Survey) and calculates a participant's experiment completion time in relation to the other participants. Prior research has shown that participants with a relative speed index above 2.0 (i.e., participants who completed the experiment two times as fast as the average participant) should be removed to exclude meaningless data (Leiner 2019. We also checked all written entries by participants for meaningless text. Overall, 47 participants failed to recall the scenario prize, had a relative speed index above two or entered meaningless text, resulting in a final sample size of 405 participants.[13] The final sample of our study participants had an average age of 27 years, 58% of the participants self-identified as female, and 54% of them had a bachelor's or higher educational degree (Table 9).

2.4.2.2. Experimental procedure and treatments

Overview and procedure. Our experimental vignette study follows a 3 x 1 between-subjects design, testing the effect of competitive reward structures on individuals' likelihood to exchange their ideas and knowledge with their competitors. Once participants joined the study, they were randomly distributed into one of the three competition treatment groups (non-competitive, lowly competitive and highly competitive reward structure). After a welcome page, participants read the scenario and made their decisions with regards to whether or not they would generally exchange ideas and knowledge (H1), share their ideas and knowledge (H2a) and absorb ideas and knowledge from others (H2b) on the three subsequent pages. After completing the scenario task, participants filled out survey questions to measure demographics and other relevant control variables (see *Measurement of control variables* for details). Table 9 lists the number of participants per treatment group and randomization checks for these variables. Except for "reciprocity: creditor ideology", no variable shows a significant difference between treatment groups at a 5% level. Since all control variables were measured after the treatment, the difference in reciprocity: creditor ideology could be due to the treatment participants received. Variables that should generally be unaffected by treatment conditions, such as age, education, gender, are more reliable for randomization checks. We find no significant differences for all these variables. Hence, we infer that our randomization was successful.[14]

[13] The percentage of participants we excluded from our initial sample is 10.40% and in line with the exclusion ratio in other studies using Prolific, e.g., Mount et al. (2021) excluded 14.18% of their initial sample.
[14] A graphical overview of the experimental procedure is available in Appendix 7.

[Insert Table 9 about here]

Experimental scenario task. As vignettes, we provided participants with the description and a related graphical illustration (see Appendix 8) of a realistic idea generation challenge on an innovation platform. Participants were informed that the contest is hosted by a company that is currently searching for new product ideas and that around 1,000 participants[15] would usually participate in contests organized by this company. Building on this, participants were informed that they participate in the described idea generation challenge and that they had already created an initial idea. Before submitting their final idea for evaluation by the company, they had the opportunity to exchange their ideas and knowledge with other participants if they wanted to. Once the final ideas were submitted, ideas would be evaluated, and a certain reward structure would be applied to award the prize to the winner(s). Information on this reward structure was manipulated to create the three experimental groups (see competition treatment for more details). Study participants were instructed to empathize with the respective scenario and make their decisions as to whether or not they choose to cooperate with their competitors (H1), share their ideas and knowledge (H2a) vs. absorb ideas and knowledge from others (H2b).

In interviews with eight pretest participants, the scenarios were well understood and led to lively ex-post discussions about the considerations one would make in such a situation. Using an experimental vignette methodology for this purpose is a suitable approach when faced with ethical and practical dilemmas in a real-effort study (Aguinis and Bradley 2014, Souitaris et al. 2020). First, field experiments face the ethical dilemma that real-world innovation contest platforms cannot vary the prize money for participants in the same challenge. Hence, we could not exercise control of the task and would need to vary it over other treatments, giving rise to effect-confounding variations. Second, real-effort experimental studies would require unfeasible amounts of prize money to induce the desired competition effects.

Competition treatment. As outlined in the development of our hypotheses, an individual's assessment of the respective likelihood to win a prize is expressed through the perceived competition and varies depending on the number of prizes in relation to the number of competitors for that prize (Deutsch 1949, Murayama and Elliot 2012). We manipulated the level of competition across

[15] By providing this information in the vignette, the number of competitors was kept constant, enabling us to solely attribute changes in cooperation behavior to our competition manipulation (level of the prize money).

treatment groups by varying the reward structure (non-competitive, lowly competitive and highly competitive) with different levels of the prize money.

In the non-competitive condition, participants should not vie with others for a prize. Hence, the reward distribution described in this scenario outlined that all the participants would receive an online shopping gift card worth EUR 50 (1000 participants x EUR 50)[16]. In the lowly competitive condition, participants were informed that those who submitted one of the 500 best ideas would receive a EUR 100 prize, keeping competition relatively low as there is a 50% chance to win a prize (500 participants x EUR 100). To induce the highest level of competition, the scenario in the highly competitive condition stated that only the participant with the single best idea would win a prize of EUR 50,000 (1 participant x EUR 50,000). As usually 1,000 individuals would participate in contests organized by the company, we do not only keep the number of participants across treatment groups constant but also the total reward amount in each scenario (EUR 50,000). The amount of the prize money and its effect on perceived competition were discussed with the pretest participants (n=8). They qualitatively verified that the manipulations outlined above induce the intended variation in the level of competition. While the increase of the monetary reward might raise concerns as an alternative explanation for the effect of competition, prior research suggests that it is the competition and not the size of the monetary reward that matters in these kinds of manipulations (for further discussion and an experimental test of this concern, see Baer et al. 2010: 833). As a manipulation check for the functioning of the experimental vignettes, we adapted the manipulation check used by Baer et al. (2010) and included three ex-post scenario items measuring an individual's perceived competition in relation to the scenario description they read.[17]

[16] Since a contest in which all participants receive a participation reward might be uncommon on real-world innovation platforms, we additionally tested a scenario for the non-competitive condition as part of which 500 out of the 1,000 participants are *randomly drawn* to receive EUR 50, and we performed a respective robustness check. The results are qualitatively similar to what is reported for the treatment with all 1,000 participants receiving a EUR 50 gift card.

[17] In a pre-study, we tested the competition manipulation with the same scale as in the experimental vignette study. The pre-study counted 49 participants in the non-competitive condition (M=3.687, SD=1.801), 48 in the lowly competitive condition (M=5.306, SD=0.970), and 53 in the highly competitive condition (M=6.069, SD=0.863). A Kruskal-Wallis test showed that the means between the experimental groups are statistically different from each other (H(2)=51.880, p=0.000). Table 9 shows the means and standard deviations for the current experimental vignette study. The statistically significant Kruskal-Wallis test indicates that our competition manipulation was successful.

2.4.2.3. Measurement of the dependent variables

To test our hypotheses and measure the likelihood of participants to cooperate under different competitive reward structures, we first asked participants whether or not they would exchange their ideas and knowledge with other participants directly after empathizing with the respective scenarios (see Appendix 7). Participants had to select "No, I would not exchange my idea and knowledge" or "Yes, I would exchange my idea and knowledge", creating a dummy variable for the likelihood to cooperate (*exchange idea and knowledge*) used for testing H1.

In the next step, we measured participants' likelihood to share ideas and knowledge with other participants using the following two questions: "How likely is it that you would post your idea for other participants to see and comment on it?" and "How likely is it that you would give feedback comments on some of the ideas of other participants?" Both questions were measured on a 7-point scale (1=very unlikely to 7=very likely). We add the answers to both questions up and create a sharing likelihood index variable.

Similarly, and as a third step after empathizing with the scenarios we used the following two questions to measure participants' likelihood of absorbing ideas and knowledge from other participants: "If knowledge from some of the other ideas you saw was helpful, how likely is it that you would incorporate this knowledge into your own idea?" and "Provided that you shared your idea with others and some of the feedback comments you received were helpful, how likely is it that you would incorporate knowledge from these comments into your own idea?" Both questions were again measured on a 7-point scale (1=very unlikely to 7=very likely). Again, the answers are added up to create an absorbing likelihood index variable. All scenario decisions were accompanied by visualizations of these decisions.[18]

2.4.2.4. Measurement of control variables

Building on existing insights on the drivers of cooperative behavior, we first include covariates that potentially explain cooperative behavior (e.g., knowledge sharing among innovation contest participants) independently of our experimental treatment. In line with this, we measured participants' level of altruism (Piliavin and Charng 1990), reciprocity attitudes (Wolfe and Loraas 2008, Wasko

[18] Screenshots of the respective pages in the online experiment are available in Appendix 10, Appendix 11, and Appendix 12.

and Faraj 2005) with respect to creditor ideology and reciprocation wariness (Eisenberger et al. (1987), trust (Chiu et al. 2006), self-efficacy (Bock and Kim 2002, Hsu et al. 2007, Kankanhalli et al. 2005), and openness (Matzler et al. 2008, Super et al. 2016).

Second, we measured variables that relate to an individual's attitudes towards competition, including a person's trait competitiveness as an indicator for how much they are affected by a competitive climate (Fletcher et al. 2008) as well as extroversion and agreeableness (Beersma et al., 2003) to account for different reactions to incentives in a cooperative context. Third, we include a measure for an individual's experience with idea generation challenges as this might influence the predisposition to participate in crowdsourcing activities (Franke et al. 2013). Lastly, we include demographic controls for age, gender, and education. All control variables were measured in the post-treatment survey. Appendix 6 lists items, scales, and reliabilities for all construct variables.

2.4.3. Results

Figure 6 reveals that the share of participants who choose to cooperate, i.e., exchange their ideas and knowledge with other contestants is surprisingly high across all experimental groups. More than half (62%) of the participants in the non-competitive condition, 41% in the lowly competitive condition, and still 32% in the highly competitive condition would cooperate with the other participants.

[Figure 6 about here]

A Chi-squared test for differences between the experimental groups shows that there are statistically significant differences in the decisions to cooperate between the experimental groups (chi2 (2, N = 405) = 26.074, p = 0.000). The number of participants who decide to exchange their ideas and knowledge gradually decreases from 85 in the no-competition group (61.9 were expected) to 53 in the low-competition group (57.8 were expected) and to 45 in the high-competition group (63.3 were expected). This suggests that an increase in the level of competition reduces an individual's likelihood to exchange their ideas and knowledge with competitors, providing support for Hypothesis 1.

Including the control variables, Table 10 additionally shows a Probit regression model to test Hypothesis 1. While the first column (Model 1) displays the effect of competition on the likelihood to cooperate only (i.e., to exchange ideas and knowledge with other contestants), the second column adds the relevant control variables (Model 2).[19] Both Model 1 and 2 suggest that an increasing level of competition has a negative and statistically significant effect on the likelihood of individuals to exchange their ideas and knowledge. While the effects of competitive reward structures on cooperation are negative ($p < 0.01$) in both competitive conditions, the negative coefficient in the highly-competitive condition is even larger in size ($p < 0.001$). Hence, the probit regression models confirm the earlier results providing support for Hypothesis 1 in the sense that an increase in competition reduces the contestants' likelihood to cooperate.

[Insert Table 10 about here]

The four other models in Table 10 show the effects of competitive reward structures on the two components of exchanging ideas and knowledge: sharing (posting ideas and providing feedback comments on others' ideas) and absorbing (incorporating knowledge from other ideas and from feedback comments received on own idea). Models 3 and 4 reveal that competition has a negative and statistically significant effect on an individual's willingness to share their ideas and knowledge with others. In line with Models 1 and 2, the coefficient in the highly competitive condition is slightly larger than the coefficient in the lowly competitive condition, indicating that an increase in competition further decreases an individual's willingness to share their ideas and knowledge with other contestants.[20] Turning to Models 5 and 6, we find little evidence that the likelihood of individual contestants to absorb ideas and knowledge is influenced by the level of competition. We only find a positive effect of low levels of competition on absorbing ideas and knowledge from others in Model 6 ($p < 0.1$) but not of high levels of competition.[21] Hence, while Hypothesis 2a cannot be rejected, Hypothesis 2b has to be partially rejected.

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[19] As a robustness check we reran the Probit models by a) pseudo-randomly dropping observations in order to have an equal number of observations in each competition group (n=384, i.e., 128 observations per group; see Appendix 13) and b) not dropping any observations due to the two exclusion restrictions for data quality reasons (n=452; see Appendix 14). The results stay qualitatively the same compared to our current sample (n=405).

[20] The figure in Appendix 15 and table in Appendix 16 further investigate how this effect differs between the two individual sharing variables (i.e., posting one's own idea and giving feedback comments on others' ideas). We find that for posting one's own idea for others to see and comment on, the no-competition group has a higher mean value (M=4.350, SD=1.900) than the low-competition group (M=3.469, SD=1.857, $p<0.001$) and the high-competition group (M=2.943, SD=1.695, $p<0.001$) in Mann-Whitney-U tests. However, for giving feedback comments, the means of the no-competition group (M=4.453, SD=1.711) and the low-competition group (M=4.117, SD=1.808, $p>0.1$) are not statistically different from each other, while the difference between the no-competition group and the high-competition group is significant (M=4, SD=1.799, $p<0.05$). In addition, the lower mean values for posting one's own idea in comparison to giving feedback indicate that individuals appear generally less likely to post their own idea and more willing to give feedback comments on others' ideas regardless of the level of competition.

[21] Appendix 15 and Appendix 16 show that the non-effect of high competition is mainly driven by the similarity of means across groups for absorbing feedback comments, while there actually is some variation in the effect of absorbing knowledge from others' ideas. More specifically, Mann-Whitney-U tests show that the low-competition group seems to have a higher average likelihood to absorb ideas

With respect to the control variables in all models, we find – not surprisingly – that altruism drives the sharing of ideas and knowledge with contestants (Model 4, $p < 0.001$) and also the overall likelihood of cooperation (Model 2, $p < 0.05$). Trust in others seems to be important for both, sharing with (Model 4, $p < 0.05$) and absorbing from them (Model 6, $p < 0.05$), and thus also positively influences the overall likelihood of cooperation (Model 2, $p < 0.05$). Finally, we find that extroversion has a negative effect on absorbing ideas and knowledge from other contestants (Model 6, $p < 0.05$).

2.5. Study 2: Configurations of conditions for cooperation in innovation contests

2.5.1. Background

While the application of social interdependence theory to innovation contests provides insights into the role of competitive reward structures on individuals' motivation to cooperate by exchanging ideas and knowledge, innovation contests are complex organizational arrangements characterized by very different manifestations in practice (Afuah 2018). Studying these manifestations is important since it enables us to understand why cooperation in innovation contests is a widespread phenomenon (Jin et al. 2021, Hofstetter et al. 2021), even though the competitive reward structures of contests would otherwise lead us to believe that cooperation should be rare.

We account for the complexity of how innovation contests are organized by following a configurational approach that allows to consider a multitude of different attributes that collectively influence the likelihood of contest participants to cooperate which each other. Configurational approaches have a rather long tradition in organizational research (e.g., Fiss 2007, Gruber et al. 2010). Defined as "any multidimensional constellation of conceptually distinct characteristics that commonly occur together" (Meyer et al. 1993: 1175), configurations resemble systems of interdependent elements. Studying configurations allows insights into the equifinality of different combinations of elements (Fiss 2007), i.e., configurations may be different but still associate with the same outcome. Innovation contests provide a favorable setting for applying such a configurational approach since prior research suggests that the relationship between competitive reward structures and cooperation might be influenced by a set of interrelated factors with respect to the problem solver's own attributes, the attributes of other participants in the contest, and the attributes of the

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and knowledge (M=5.398, SD=1.549) from others compared to the no-competition group (M=4.898, SD=1.720, $p<0.05$) and the high-competition group (M=4.729, SD=1.888, $p<0.01$).

contest itself (e.g., Füller et al. 2014, Jin et al. 2021, Kathan et al. 2015, Majchrzak and Malhotra 2020). Studying those configurations promises insights that would otherwise be out of reach if analyses focused on individual elements (Miller 1981).

2.5.2. Methods

To implement the configurational approach, we first explore factors that potentially influence individual contestants' decision to cooperate under competitive conditions (steps 1-3) and then use these factors as an input to an adaptive choice-based conjoint (ACBC) analysis in step 4. Figure 7 provides an overview of the process in Study 2.

[Insert Figure 7 about here]

The exploration of potential influencing factors follows a multi-step approach as part of which we cycled back and forth between identifying and classifying potential factors from the existing literature with respect to (a) the focal problem solver's own attributes, (b) the attributes of other participants in the contest, and (c) the attributes of the contest itself (steps 1 and 2), and empirically validating and extending the list of potential factors by means of qualitative interviews with individuals who participated in real-world innovation contests on platforms that enable cooperation (step 3). Interview participants were first asked to openly reflect upon different factors that influence their decision to exchange ideas and knowledge with other contestants on the respective platform. After openly sharing their insights, they were then invited to assess, comment on and specify the attributes we derived from the literature review. During the ACBC in step 4, study participants were exposed to the same scenarios as in Study 1, but instead of deciding whether or not to cooperate, they had to identify how important each of the attributes identified in steps 1-3 were for their decision to cooperate, i.e., exchange their ideas and knowledge with contestants.

2.5.2.1. Exploration of factors that influence individuals' decision to cooperate

To explore the drivers of cooperation under competitive conditions, we first reviewed the existing literature in different fields including economics, management, psychology, sociology, and strategy and inspected existing innovation contest platforms (step 1). With respect to the latter, we particularly explored platforms that have been mentioned or studied in research we are building upon: LEGO Ideas (e.g., Antorini et al. 2012, Krishnan 2013), Kaggle (e.g., Jin et al. 2021), Topcoder (e.g., Lifshitz-Assaf 2018, Majchrzak and Malhotra 2020, Riedl and Woolley 2017), and OpenIDEO (e.g., Hofstetter et al. 2021).

Prior to validating the list of factors in step 3, we categorized all the attributes identified in step 1 into the three main categories: (a) *Attributes of the focal participant* refers to attributes that describe the focal problem solver who makes a cooperation decision; (b) *Attributes of other participants* includes attributes that relate to the other participants in the innovation contest the focal participant would potentially exchange ideas and knowledge with; and (c) *Attributes of the contest* contains all attributes that are related to the platform environment and the challenge to be addressed in the contest (step 2).

To validate the attributes within these three main groups, we applied a theoretical sampling approach to select qualified interviewees (Robinson 2014). First, we interviewed individuals who had participated in such innovation contests on online platforms before. Second, we strove to interview participants from a variety of different platforms that allow for cooperation under competitive conditions. Third, we gathered interviewees with a different level of prior experience in such contests, including contest participants at a beginner level (<10 prior contest participations), an intermediate level (10-20 prior contest participations), and an advanced level (>20 prior contest participations). Once we reached information saturation in the sense that no new attributes were added to our list of attributes by new interviewees, we stopped conducting more interviews (Strauss and Corbin 1998). Our final sample consists of 15 interviewees. Table 11 provides a detailed description of our interview sample along the lines of the selection criteria described above and with respect to nationality and gender.

[Insert Table 11 about here]

The interviews were conducted by two of the authors, following a semi-structured interview guide. Each interview was recorded and subsequently transcribed. The first questions were open-ended and asked participants for their reasons to exchange ideas and knowledge with other participants in the contest (or not). Following this part, we provided interviewees with the list of potential attributes identified in steps 1 and 2. While showing our interviewees the list of potential attributes, we asked them to discuss each factor and indicate whether an attribute is relevant for their decision to cooperate on the platform we interviewed them about and, if so, which attribute levels were important for that decision.

Based on the interview transcripts, two of the authors coded the interviews in a simultaneously deductive and inductive procedure using NVivo. The attribute list derived from the literature served as the deductive codebook (DeCuir-Gunby et al. 2011), while any new attribute that was mentioned in an interview was inductively given a new code. Once new attribute codes emerged inductively from the interviews, we cycled back to the literature to explore potential prior research we may not have captured in step 1. The coding resulted in a total of 81 codes that represent attributes and attribute levels.

Table 12 shows the results of this process, displaying a list of all attributes and indicating whether an attribute was derived from our literature and platform review prior to the interviews and validated (or not) during the interviews, or whether an attribute was inductively derived from the interview data and added to the list. In case we identified relevant literature sources ex-post, we included them in the list and classified the attribute as "validated". Overall, 11 attributes were validated, four were not and four new attributes were added inductively based on the interviews, resulting in a total of 15 attributes (and their attributes levels, see Appendix 17). These 15 attributes form the basis for the configurational approach (ACBC) to identify those attributes that together influence the likelihood of contest participants to cooperate which each other.

[Insert Table 12 about here]

2.5.2.2. Identification of configurations that lead individuals to cooperate under competitive conditions

To investigate the attribute importance levels of interrelated attributes and identify attribute configurations across levels of competition, we conduct an ACBC analysis and a related ensemble cluster analysis. The ACBC analysis is embedded in an online survey for participants and builds upon traditional choice-based conjoint (CBC) methods. CBC analysis has originally been used in the marketing literature to investigate individual decision-making preferences (e.g., Green and Rao 1971, Toubia et al. 2007) but has recently been adopted in other fields, such as entrepreneurship (Warnick et al. 2018), management (Beck et al. 2019), and strategy (Schillebeeckx et al. 2016).

CBC analysis offers insights into complicated tradeoffs, while presenting realistic and relevant constraints (Green et al. 2001, Green and Rao 1971, Wind et al. 1989). For example, a car manufacturer may want to know which car model would be preferred by consumers. Car model attributes might vary in terms of color (attribute levels: black, green, white), engine (e.g., electric, gas, hybrid), or type (minivan, SUV, truck). A CBC would then allow car manufacturers to identify the attribute (e.g., engine) importance weights and the attribute level (e.g., electric) utilities.

By extending and modifying the CBC, an ACBC has two additional features important to our study. First, the ACBC allows for the consideration of a larger set of attributes (Beck et al. 2019, Orme 2014). In a classical CBC, the number of attributes per choice task must be limited to prevent information overload and allow a meaningful consideration of attribute levels (Eggers and Sattler 2011). This entails that the most important attributes would need to be predetermined by the researcher. However, given the exploratory nature of Study 2, we do not know which of the many attributes are the most important for the decision to cooperate under competitive conditions ex-ante and we are interested in revealing them. Hence, participants choose the attributes they find most important and consider only these in the choice tasks. Second, the ACBC allows for the adaptation of a participant's choice options based on their previous answers (Orme 2014, Toubia et al. 2007, Toubia et al. 2004). This allows participants to make compensatory decisions, such as deciding on "must-have" or "unacceptable" attribute levels, and increases both participants' engagement and accuracy of the analysis (Toubia et al. 2007).

While the results of the ACBC offer importance weights and utilities for the entire sample, considering only the pooled aggregation of heterogeneous data might mask underlying differences of sub-groups (Flöthmann et al. 2018, Hatten et al. 1978, Orme and Johnson 2008). Hence, clustering sub-groups into homogeneous preference clusters can reveal useful insights about heterogeneity in the preference structures for cooperation. For this purpose, we used Sawtooth Software's Convergent Cluster Ensemble Analysis (CCEA) package that derives a consensus solution from multiple runs of different clustering methods (e.g., hierarchical, k-means, neural networks, etc.) (Orme and Johnson 2008, Retzer and Shan 2007, Strehl and Ghosh 2002).

2.5.2.3. ACBC participants

Using Prolific Academic, we recruited a total of 632 participants to take part in Study 2. Participants were compensated with USD 4.98 for completing a task that, on average, took them 26 minutes. Following the response quality discussion from Study 1, we excluded participants if they failed the correct recollection of our competition treatment (see Appendix 6 for the question and items) or if the time they spent on each of the conjoint task pages was, on average, less than ten seconds. This resulted in the exclusion of 60 participants of which all failed the recollection check, five who took less than ten seconds, and five who failed on both aspects. The final sample size thus comprises of 562 ACBC participants.[22] Table 13 displays the sample descriptives per treatment group. On average, our ACBC participants were 27 years old, 41% self-identified as female, and 58% had completed a bachelor's or higher educational degree.

[Insert Table 13 about here]

2.5.2.4. ACBC experiment process

At the beginning of the ACBC process, participants were randomly assigned to one of the three competitive reward structure groups already used in Study 1 (no, low and high competition) and presented with the respective scenario text and an explanation of what they need to decide on.[23] Participants then read a list of the attributes that could potentially influence their decision to exchange their ideas and knowledge with other contestants (Appendix 20). Based on this list, participants had to select the five attributes that would be most important to them in their decision to exchange their ideas and knowledge (Appendix 21)[24] and then indicate which level of the selected attribute would make them most likely to do so (Appendix 22). The software then used these inputs to generate up to 8 x 4 screening situations across which the attribute levels were displayed in different configurations. For each of these configurations, participants had to decide whether or not they would cooperate, i.e., exchange their ideas and knowledge (Appendix 23). Depending on the preference decisions, participants would see a "must-have" or "unacceptable" question in-between these configurations. As final ACBC tasks, the software would display multiple choice task tournaments, in which three configurations were depicted of which participants had to choose the one where they would most likely exchange their idea and knowledge with their competitors (Appendix 24). Lastly, participants had to answer a survey regarding relevant control variables. As the context of the experiment stayed the same, we used the same control variables as in Study 1. Table 13 lists the randomization checks

[22] The percentage of participants we excluded from our initial sample is 11.08% and in line with the exclusion ratio in other studies using Prolific, e.g., Mount et al. (2021) excluded 14.18% of their initial sample. In our Study 1, we excluded 10.40%.
[23] See Appendix 18 for a graphical overview of the process.
[24] The number of attributes, i.e., five, was based on a) literature recommendations (e.g., Green and Srinivasan 1978, Orme 2006), suggesting that 5 to 6 attributes are the maximum, but less is better, if the attribute text is rather long; and b) pretest interviews in which 6 attributes were too many for the majority of interviewees. See Appendix 19 for an experiment screenshot.

and the manipulation check for the Study 2 participants.[25] Except for trait competitiveness, no variable shows a significant difference between treatment groups at a 5% level. The difference in trait competitiveness may be due to being measured as part of the survey after the treatment. There are no differences in the variables that should generally be unaffected by treatment conditions, e.g., age, education, or gender. This suggests that our randomization was successful. Appendix 6 provides the items, scales, and Cronbach's alphas for all construct variables.

2.5.2.5. Attributes included in ACBC

The attributes that participants read about and could select in the ACBC task were based on the results of steps 1 to 3 (see Figure 7 and Table 12). Before we ran the ACBC, we pretested the survey tool in think-aloud interviews (online) with ten participants from Prolific and in in-person interviews with nine participants from a master and PhD program at one of the authors' universities (the average interview length was 55 minutes). The goal of the pretest interviews was to ensure that all attributes and instructions in the survey were clearly understood. Hence, the 19 pretest interviewees were asked to take the online survey and speak aloud about their thoughts with respect to the attributes and the related attribute levels as well as the attribute configurations that influence their decision to exchange ideas and knowledge with their competitors, given the three different competitive conditions. All interviews were conducted by one of the authors, recorded and analyzed for potential modifications and improvements to the initial study set-up.[26]

2.5.3. Results

We first explore the attributes that differ with respect to having been selected as being most important in the first step of the ACBC task (where participants had to select the five attributes that most likely influence their decision to cooperate) across the different competitive reward structures (Table 14). Then, we use a Hierarchical Bayes (HB) analysis to investigate the importance weights of each attribute and the utilities of each attribute level (Table 15) across competitive conditions.[27] Finally,

[25] A pairwise correlation table can be found in Appendix 25.
[26] We further tested our ACBC design using Sawtooth Software Lighthouse Studio 9 software's built-in robotic participant simulation feature. This test confirmed that all attribute levels appear about three times per respondent and the standard errors related to the attribute levels were below the 0.05 threshold (cf. Orme 2015, 2019).
[27] Following the recommendations by Orme (2021) and Orme and Williams (2016), we ran the HB analysis with 60,000 iterations and 60,000 draws and set the prior variance to 1, prior degrees of freedom to 2, and the random seed to 1.

we used the zero-centered individual utilities from the HB estimation as input data to cluster the preference structures in each competitive condition. By doing so, we identify different configurations of attributes ("homogeneous preference clusters") that together influence an individual's decision to exchange ideas and knowledge with other contestants under non-, lowly and highly competitive conditions (Table 16).

Comparing the results form stage 1 in the ACBC task reveals that four out of 15 attributes were significantly more or less often selected as being most important for the decision to cooperate (or not) with other contestants in the different competitive conditions (Table 14). More specifically, we find that the existence of rules that prevent others from pure copying ("copying rules") was selected more often than expected in both the low and high competition groups and less often in the no-competition group ($p < 0.01$). Both the effort required for sharing ideas and knowledge ($p < 0.001$) as well as for incorporating ideas and knowledge ($p < 0.10$) were more often than expected selected in the no-competition group. Finally, the personal knowledge and skills that enable a focal participant to win were more often (less often) than expected selected as a relevant decision factor in the low and high competition groups (no-competition group, $p < 0.001$).

Although copying rules were among the five most important attributes to influence the cooperation decision across competitive conditions (Table 14), they were the most often selected attribute in all competition groups in absolute terms. Two more (of five possible) attributes (the existence of rewards for sharing ideas and knowledge with others, and the helpfulness of the knowledge shared by others) were among the three most frequently selected factors in all competition groups (for a ranking of the five most often selected attributes in stage 1 of the ACBC see Appendix 26).

[Insert Table 14 about here]

This is surprising as one would, for example, expect that an attribute like the existence of rules that prevent others from pure copying might be less important for making cooperation decisions when there is no competition among participants. To critically question common beliefs about this and challenge our findings from the factor exploration, we conducted an additional vignette study via Prolific. We presented participants of this additional study (n=211) the design of our Study 2 and asked them to estimate which factors they think Study 2 participants had chosen as being among the five most important ones when making a cooperation decision under (non-, lowly and highly) competitive conditions. After excluding 43 participants who failed the manipulation check (i.e., could not recall what the prize money was in the respective scenario), five who answered the survey too quickly, and eleven whose educational degree was below a PhD, the final sample consists of 158 study participants with a PhD degree currently located in the US or the UK. Randomization checks based on age, gender, and experience with innovation contests confirmed that our randomization across competitive conditions worked ($p > 0.1$).

The results of this prediction study reveal an interesting pattern. While the existence of rewards for sharing ideas and knowledge with others as well as the helpfulness of ideas and knowledge shared by others, the complexity of the problem to be solved and the effort it takes focal participants to share their ideas and knowledge with others were among the five most frequently selected attributes in all groups, though on different ranks each, the existence of rules that prevent others from pure copying was not even in the top five in any of the competition groups (Appendix 27). This clearly indicates that our Study 2 results are not obvious and worth further investigation.

Looking into the average attribute importance weights and attribute-level utilities across competition groups, we see that the existence of rules preventing pure copying, the presence of rewards for sharing ideas and knowledge with others, and the helpfulness of ideas and knowledge shared by others are the three most important attributes in absolute terms in all competition groups. However, we observe several differences across competition groups and attribute-level utilities (Table 15). For instance, the most important attribute level in the no-competition group is the existence of rewards for sharing ideas and knowledge (importance weight 92.60%), whereas it is the existence of copying rules in the low-competition (144.86%) and in the high-competition group (170.58%). While the order of important attributes within the three competitive conditions also differs from each other for the less important attributes, it is more interesting to look at the differences in importance weights of individual factors between the competition groups. Here, trends can be clearly seen, such as how the importance of individual factors in relation to the decision to cooperate steadily increases or decreases when competition moves from no to high. While intrinsic motivation (fun, learning, interest in the topic), the existence of copying rules as well as high problem complexity increase in importance for making a decision to cooperate when competitive conditions increase, extrinsic motivation (winning the prize and career benefits), having all relevant knowledge and skills to win the contest oneself, the similarity of the ideas and knowledge shared with oneself compared to one's own and low problem complexity become more important for deciding against cooperation. On the other hand, little effort to share one's ideas and knowledge and to absorb others' ideas and knowledge, the possibility of sharing parts of one's initial idea as well as the existence of rewards for sharing become less important for deciding to cooperate when competition increases. In a similar vein, considerable efforts to share ideas and knowledge and to absorb the ones of others, the possibility of sharing one's entire initial idea, different but not complementary knowledge being shared with oneself and having only a few hours left until submission become less important for deciding against cooperation when competition increases. The other factors do not show a clear trend across increasing levels of competition.

[Insert Table 15 about here]

Finally, to address the complexity in the decision-making process contest participants face when deciding whether to cooperate under competitive conditions (or not), we investigate different configurations of attributes that are homogenous sub-clusters. For doing so, we use the zero-centered individual utilities from the HB estimation as the input data to cluster the preference structures in each competition group. We identify three clusters in the non-competitive condition and two clusters each in the lowly and highly competitive condition (Table 16).

[Insert Table 16 about here]

In each competition group we find a cluster (N1, L1 and H1) in which the cooperation decision is mainly influenced by the existence of rules that prevent others from pure copying. "Misappropriation hazards" seem to be the most dominant driver of deciding whether to exchange ideas and knowledge with other participants (or not) in these clusters, regardless of whether or not there is competition. The second (no-, low- and high-competition group) and third (no-competition group) clusters are dominated by factors related to motivation (N2, N3, L2, H2). In the non-competitive condition, we identify two different clusters with one dominated by the existence of rewards for sharing ideas and knowledge with others (extrinsic motivation) and the other one by fun and learning as the main (intrinsic) motivation to cooperate with other participants. While the second cluster in the lowly competitive condition is also dominated by the existence of rewards for sharing ideas and knowledge with others (extrinsic motivation), the second cluster in the highly competitive condition again focuses on the intrinsic motivation of contest participants to have fun and to be able to learn something by cooperating with others. Interestingly, all motivation-related clusters are an interrelated configuration among at least two or more attributes, with the "helpfulness of other participants" being included as an interrelated attribute in most of these configurations except for N3 (intrinsic-motivation focus; no competition) and the complexity of the problem to be solved included in all of them as well, except for N2 (extrinsic-motivation focus, no competition). The focal participants' own abilities and skills to win the contest seem to only matter in the competition groups (low and high).

2.6. Discussion

This paper set out to answer how competitive reward structures in innovation contests influence the likelihood that individuals will choose to cooperate, and what the conditions are under which competition affects the cooperative behavior of contestants. While innovation contests have become an increasingly important approach for managing firms' innovation efforts (e.g., Boudreau et al. 2011, Körpeoğlu and Cho 2018, Terwiesch and Xu 2008) and many contest platforms allow individual participants to cooperate with fellow contestants (e.g., Hutter et al. 2011, Riedl and Seidel 2018), little is known about the effects and boundary conditions of competitive reward structures on cooperative behavior among contest participants. This is interesting as allowing for cooperation in innovation contests constitutes a public good dilemma (Cabrera and Cabrera 2002) in which all participants could potentially benefit from the knowledge exchanged (Olson 1965). Sharing knowledge, however, is also costly (Cabrera and Cabrera 2002), and social interdependence theory would lead us to believe that competitive reward structures are not conducive to knowledge sharing as only one or a few individuals are able to win a prize in the contest (Beersma et al. 2003, Deutsch 1949, Johnson 2003, Johnson and Johnson 1989, Tjosvold 1989).

Uncovering the effects of competitive reward structures on cooperation, however, is challenging as the existing literature suggests that the relationships are affected by a set of interrelated factors including attributes of the focal participant, those of the other participants and attributes of the contest itself (e.g., Chan et al. 2022, Füller et al. 2014, Jin et al. 2021, Kathan et al. 2015, Majchrzak and Malhotra 2020). To understand the boundary conditions of social interdependence theory, it is thus crucial to identify the conditions under which competitive reward structures prompt cooperation (or not) between individuals (Kistruck et al. 2016).

We address our research questions in two studies. Study 1 conducts an experimental vignette study focusing on how different competitive reward structures (no, low and high levels of competition operationalized by higher levels of monetary incentives) affect an individual's likelihood to cooperate in innovation contests. Cooperation, in this context, is conceptualized as the interactive and relational behavior between individuals to achieve their individual goals (Bullinger et al. 2010, Chen et al. 1998, Milton and Westphal 2005) and operationalized as the individuals' likelihood to exchange their idea and knowledge with other contestants.

Our results in Study 1 show a negative effect of competitive reward structures on the likelihood to cooperate, i.e., to exchange their ideas and knowledge with other contest participants. We furthermore find that this negative effect is due to a decrease in the individuals' likelihood to share their ideas and knowledge rather than likelihood of absorbing ideas and knowledge from other contestants which we largely find to be unrelated to competition. Our results inform the debate about the conditions under which individuals share their knowledge with others in online settings (e.g., Jarvenpaa and Majchrzak 2010, Wasko and Faraj 2005) and highlight that – while individuals still cooperate under competitive conditions – competitive reward structures decrease the likelihood of cooperation.

In Study 2, we follow a multi-step configurational approach examining the interrelation of attributes that drive an individual's decision of whether or not to cooperate under competitive conditions. We identify and categorize potential drivers of cooperation under competitive conditions which are then used as input for in an ACBC study and a subsequent cluster ensemble analysis. It turns out that several (interrelated) factors influence the decision-making process of individuals to cooperate with other contestants. More specifically, we find that the most important attributes, in absolute terms, across all three competitive reward structures are the existence of rules that prevent other participants from merely copying ideas and knowledge that a focal participant had shared, the existence of rewards for sharing ideas and knowledge, and the helpfulness of knowledge that had been shared by other participants. Previous literature has investigated these attributes in regard to how participants navigate the paradox of openness and ensure value appropriation when sharing knowledge in innovation contests (Foege et al. 2019), the effect of sharing rewards on cooperation outcomes (Baer et al. 2010, Beersma et al. 2003), and reciprocity considerations in online communities (Kathan et al. 2015). Our findings emphasize their significance for individual decision-making processes.

Considering the relative importance of different attributes of the focal participant, other participants and the contest itself under different competitive conditions, however, reveals interesting patterns with respect to the drivers of cooperation and non-cooperation when competition increases (Figure 8). While, for example, intrinsic motivation, the existence of copying rules and a high level of problem complexity are factors that become more important for deciding to cooperate under increased competition, extrinsic motivation as well as having all relevant knowledge and skills to win the contest oneself and a low level of problem complexity become more important for deciding against cooperation.

The cluster ensemble analysis provides an in-depth analysis of the attribute bundles across competitive reward structures. We find that two or three clusters emerge in each competitive condition (Figure 9). The first cluster each is dominated by misappropriation hazards, i.e., individuals' consideration of whether or not the ideas and knowledge they shared is protected from misuse by other participants, i.e., from mere copying and appropriating rather than recombining it. The second (and third) cluster in each competition condition combines a mix of attributes related to intrinsic and extrinsic motivational considerations and other factors. More specifically, participants in the non- and lowly-competitive reward structures consider whether idea and knowledge sharing rewards are in place (extrinsic motivation) combined with other factors, such as the complexity of the problem to be solved or the helpfulness of knowledge provided by other participants. In the highly-competitive reward structure, participants consider attributes related to intrinsic motivation, such as the motivation to participate in the challenge for which fun and learning are the most important manifestations combined with other factors like the focal participants' own knowledge and skills and the purpose of the contest. Comparing the clusters across competitive conditions (Figure 10) clearly shows the similarities and differences: While there is one group of individuals in each competitive condition who mostly and to a comparable extent fears misappropriation of their ideas and knowledge, the other group cares about a larger set of different interrelated factors with motivational aspects (extrinsic in the no and low competition groups and intrinsic in the high competition groups) being comparably important in all competitive conditions and the existence of rewards for sharing knowledge – while also present in all of them – mostly important in the non-competitive condition. Intrinsic and extrinsic motivation, especially their trade-off, are a longstanding subject of scholarly interest (e.g., Amabile 1993, 1994, Cerasoli et al. 2014, Liang et al. 2018). We add to this body of research by highlighting that the presence of extrinsic motivation may not be sufficient for individuals to cooperate under highly competitive reward structures. Intrinsic motivation may constitute a prerequisite for enabling the combination of fruitful knowledge exchange and individual effort.

In that sense, our research deepens the understanding of when individuals in innovation contests engage in coopetition. We extend social interdependence theory by examining how competitive reward structures interact with innovation contest configurations (Johnson and Johnson 1989, Johnson 2003, Beersma et al. 2003) to explain why cooperation still occurs even though we should not expect cooperation under competitive conditions. Hence, we advance a model of individual-level coopetition in innovation contests. Previous literature on coopetition has predominantly focused on the firm level (Cassiman et al. 2009, Gnyawali and Park 2011, Ritala and Hurmelinna-Laukkanen 2013) or unit level in multiunit organizations (Tsai 2002). We extend this literature by providing an understanding of how competitive dynamics facilitate innovation cooperation through new forms of engagement with individuals outside of a firm's boundaries. In particular, these insights show conditions under which individuals, who compete for the same prize, decide to cooperate which in turn may harness the potentials of both the recombination of knowledge (facilitated by cooperation) and increased individual effort (facilitated by competition) (Boudreau et al. 2011, Singh and Fleming 2010).

Our results have important managerial implications for the organization of innovation contests as an emerging organizational form (Franke et al. 2013). First, our findings on the negative effects of competitive reward structures on individuals' willingness to exchange their idea and knowledge with other contestants caution against implementing high-powered competitive incentives. While higher competition can be beneficial for idea quality in contests without cooperation (Boudreau et al. 2011, Körpeoğlu and Cho 2018, Terwiesch and Xu 2008), our findings indicate a trade-off between the effort-increasing effect of competition and the benefits of knowledge recombination through cooperation. Second, our results suggest that the existence of rules preventing contestants from mere copying others' ideas and knowledge and the existence of rewards for sharing ideas and knowledge with others are important for deciding for or against cooperation, although with different importance levels and in combination with different other attributes of the focal contestant and the other contestants. As these are factors related to the contest itself, contest organizers have a direct influence on them. Managers are thus well advised to consider implementing one or both of them (subject to other conditions such as the type of crowd motivation or the complexity of the problem) in an innovation contest when inducing cooperative behavior is the objective.

2.7. Conclusion

While our research offers important implications regarding the boundary conditions of social interdependence theory as well as for the organization of innovation contests, our research is not without limitations which, in turn, offer opportunities for future research. First, despite our collection of a heterogeneous sample of interviewees in Study 1, we did not gather interviewees from less well-known platforms that might be smaller in participant size or different in their behavioral dynamics. Research on innovation platforms and online communities shows the variety in innovation platform purposes (Boudreau and Lakhani 2013, Kohler and Chesbrough 2020) that may influence which participants are motivated to participate (Lakhani and Wolf 2003, Ye and Kankanhalli 2017) and how they work together (Majchrzak and Malhotra 2020). While we include the purpose of the challenge, the motivation to participate in the challenge, and the type of knowledge to be shared in our attribute list, we cannot rule out that there may be other and potentially more subtle differences across platforms that our measures do not fully capture. Hence, it is promising to investigate how competitive reward structures influence an individual's willingness to cooperate across different types of platforms and contests.

Next, both our studies are based on an experimental vignette-study design. While we extensively corroborated the vignette's efficacy, especially in terms of its comprehension and perceived realism, it would be promising to examine how the competitive reward structures on existing innovation contest platforms affect cooperation decisions. Influential factors, such as trust (Jarvenpaa and Majchrzak 2010, Ye and Kankanhalli 2017) or reciprocity (Kathan et al. 2015), might materialize in different cooperative behaviors if there is a real prize at stake. For example, a qualitative study in which participants' decision-making processes are observed could provide in-depth insights into the drivers of cooperation decisions across different competitive reward structures and platforms.

Lastly, and related to the previous point, our vignette studies suggested participants to think about sharing ideas and knowledge (e.g., feedback on others' ideas) as a general concept. However, knowledge (e.g., comments or specific feedback) exchanged between or information available about other contestants in innovation contests might vary considerably in a real-world context (e.g., Chan et al. 2022, Majchrzak and Malhotra 2020) and may – independently of the competitive reward structure – block or facilitate cooperative behavior among contestants. Future field studies could particularly look into the different information provision and knowledge exchange processes and how they influence cooperative behavior among contestants. Based on this, interventions to structure and facilitate the cooperation process might be developed and tested.

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2.9. Tables and figures

Tables

Table 9: Study 1 sample descriptives, randomization checks, and manipulation check

	No competition		**Low competition**		**High competition**		**Equal distribution across experimental groups**	
Variables[a]	Mean	SD	Mean	SD	Mean	SD	Test[b]	p-value
Age	26.650	7.971	26.438	9.512	27.793	9.342	K-W	0.139
Agreeableness	0.894	0.590	0.918	0.572	0.830	0.620	K-W	0.435
Altruism	5.367	0.949	5.323	1.063	5.419	0.929	K-W	0.931
Crowdsourcing experience[c]	1.350	0.537	1.398	0.593	1.314	0.524	Chi-squared	0.684
Education[d]	3.745	0.758	3.656	0.747	3.743	0.743	Chi-squared	0.782
Extroversion	0.389	0.777	0.656	0.762	0.527	0.856	ANOVA	0.084
Gender (1=female)	0.584	0.495	0.586	0.494	0.579	0.496	Chi-squared	0.992
Openness	2.329	0.584	2.260	0.598	2.283	0.641	K-W	0.399
Perceived competition[e]	3.041	1.565	5.385	0.933	6.067	0.835	K-W	0.000
Reciprocity: Creditor ideology	4.389	1.119	4.574	1.110	4.741	1.093	ANOVA	0.031
Reciprocity: Reciprocation wariness	3.423	0.893	3.504	0.873	3.462	0.917	K-W	0.728
Self-efficacy	5.030	1.038	5.157	0.869	5.096	1.111	K-W	0.782
Trait competitiveness	4.870	1.156	5.172	1.106	5.005	1.104	K-W	0.072
Trust	4.482	1.191	4.484	1.209	4.321	1.356	K-W	0.572
Observations[f]	137		128		140			

Notes.
[a] See Appendix 6 for constructs, items, scales, and scale reliabilities.
[b] All variables were asked ex-post to the scenario task. Except for extroversion and reciprocity: creditor ideology, all continuous variables are not normally distributed. Hence, we use analysis of variance tests (ANOVA) for the former and non-parametric Kruskal-Wallis equality-of-populations rank tests (K-W) for the latter variables. For categorical variables we use Pearson's chi-squared tests (Chi-2). ;
[c] Crowdsourcing experience scale: 1 = Never, 2 = 1-3 times, 3 = More than 3 times.
[d] Education scale: 3 = High school or lower level, 4 = Bachelor's or equivalent level, 5 = Master's or higher level.
[e] Perceived competition represents our manipulation check for the competition across the scenarios. This means that a p-value < 0.05 indicates that our treatments had the intended effect of inducing different levels of competition.
[f] We excluded 47 participants from our sample that failed to recall the competition prize in the scenario, finished the survey more than 2-times quicker than the average participant, or inserted meaningless text (cf. Leiner, 2019).

Table 10: Probit and OLS regression results

Variables	Cooperation (y/n) (Exchange ideas and knowledge)		Sharing likelihood		Absorbing likelihood	
	Probit		OLS		OLS	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Low competition	-0.524***	-0.529**	-1.217**	-1.184***	0.532	0.589+
	(0.156)	(0.163)	(0.369)	(0.357)	(0.323)	(0.326)
High competition	-0.770***	-0.812***	-1.860***	-1.835***	-0.295	-0.162
	(0.155)	(0.162)	(0.361)	(0.349)	(0.315)	(0.320)
Agreeableness		-0.016		0.431		0.236
		(0.148)		(0.319)		(0.292)
Altruism		0.177*		0.741***		0.177
		(0.087)		(0.187)		(0.171)
Extroversion		-0.052		-0.039		-0.430*
		(0.105)		(0.223)		(0.204)
Openness		0.145		-0.014		0.099
		(0.119)		(0.256)		(0.234)
Reciprocity: Creditor ideology		0.117+		0.145		-0.083
		(0.065)		(0.139)		(0.127)
Reciprocity: Reciprocation wariness		-0.005		-0.002		-0.177
		(0.083)		(0.182)		(0.166)
Trait competitiveness		-0.056		0.019		0.240+
		(0.068)		(0.149)		(0.136)
Trust		0.151*		0.287*		0.263*
		(0.062)		(0.131)		(0.120)
Self-efficacy		-0.139+		-0.303+		0.064
		(0.078)		(0.169)		(0.155)
Age (log.)		0.003		-0.581		-0.607
		(0.270)		(0.588)		(0.538)
Crowdsourcing experience (1-3 times)		0.049		0.017		-0.081
		(0.153)		(0.331)		(0.302)
Crowdsourcing experience (> 3 times)		0.307		0.186		0.279
		(0.348)		(0.769)		(0.704)
Education (Bachelor's or equivalent)		-0.090		0.080		-0.121
		(0.154)		(0.333)		(0.304)
Education (Master's or higher)		-0.108		0.301		0.331
		(0.199)		(0.434)		(0.397)
Gender (1 = female)		-0.076		-0.292		-0.016
		(0.137)		(0.298)		(0.273)
Constant	0.307**	-1.073	8.803***	5.995*	10.453***	9.525***
	(0.109)	(1.212)	(0.256)	(2.658)	(0.224)	(2.431)
Observations	405	405	405	405	405	405
Pseudo R2	0.047	0.098				
LR chi2	26.32	54.47				
Prob > chi2	0.000	0.000				
R-squared			0.064	0.193	0.017	0.072
F-statistic			13.666	5.428	3.388	1.756
Prob > F			0.000	0.000	0.035	0.032

Notes. Coefficients are shown. Standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The sharing and absorbing likelihoods in models 3-6 are an index of the two individual sharing and absorbing variables, each. The results for all four individual sharing and absorbing variables are available in Appendix 15 and Appendix 16.

Table 11: Interview sample description

Interviewee	Active on crowdsourcing platform	# of prior contest participations[a]	# of discussion participations	Country	Gender	Interview duration (in min.)
I1	Kaggle	<10	51–200	USA	Male	37
I2	Kaggle	<10	10–50	UK	Male	33
I3	Kaggle	<10	<10	India	Male	18
I4	Kaggle	<10	<10	USA	Male	N/A[b]
I5	Kaggle	<10	<10	Israel	Female	40
I6	Kaggle	>20	51–200	Ukraine	Male	46
I7	Kaggle	<10	10–50	Germany	Male	N/A
I8	Kaggle	10–20	51–200	Russia	Male	25
I9	Kaggle	>20	51–200	USA	Male	43
I10	Kaggle	>20	>200	USA	Male	N/A
I11	Kaggle	10–20	>200	Romania	Male	N/A
I12	OpenIDEO	<10	N/A	Hungary	Male	75
I13	OpenIDEO	<10	N/A	Sweden	Female	45
I14	Topcoder & Kaggle	>20	<10	Egypt	Male	19
I15	Topcoder & Kaggle	10–20	<10	Germany	Male	14

Notes.

[a] For reference, the average length of one contest on Kaggle is 69.6 days and has an average of 1,557.76 participants (Jin et al. 2021). While our interviews show that participants do not necessarily spend the full contest length being active on the platform, participants usually spend at least a couple of days or weeks on their submission. This means that participating in 10-20 contests already entails a considerable amount of time investment, on average.

[b] Interviewees I4, I7, I0, and I11 were not able to do an audio interview but agreed to respond to our interview questions in writing.

Table 12: Results of the exploration of factors that influence an individual's decision to exchange their idea and knowledge with contestants

Interview assessment [a]	Category	Attribute	Exemplary literature references	Exemplary interview quote
Validated	(a) Attributes of the focal participant	My main motivation to participate in the challenge	Jeppesen and Frederiksen (2006); Gallus (2017); Lakhani and Wolf (2003); Wasko and Faraj (2005); Wiertz and de Ruyter (2007)	"Yes. If I like the competition a lot, I usually feel the urge to share my thinking with everybody else" (I11) "When I don't know things about it then I probably would be more willing to share because I'm learning things and when I learn I want to also share more because I learned something" (I8) "[A]ctually the learning curve if you are working alone based on my experience is better" (I14)
	(a) Attributes of the focal participant	My personal knowledge and skills that enable me to win	Patel et al. (2012)	"[T]hose who have higher rankings, they generally share something and we [who have lower rankings] read it and upvote it." (I5) "That was mainly because I didn't have anything that was worth sharing. […] Because I tried a lot of different techniques, but I couldn't outdo some very simple techniques that other people really demonstrated worked well in those notebooks." (I2) "If I'm already in a high position at the leaderboard (top 10), then I'd be hesitant to share info that could give a competitive edge. If my position is lower, I'd share a lot more - anything that was useful for me and wasn't discussed in forums already" (I8)
	(a) Attributes of the focal participant	Type of knowledge I can share with others	Alexy et al. (2013); Foege et al. (2019); Henkel (2006); Steinel et al. (2010)	"If I'm in it to win, I would only share some basic ideas, but not my secret sauce that sets my submission apart." (I7) "So, if it's a general knowledge or individually specific knowledge. I put it—when previously I told you that if something gives a competitive edge then it's probably individual specific knowledge. So, this is something I'll think carefully before sharing. Other things I'll just share, like for example there is a useful paper for this competition or an approach that didn't work or some useful GitHub repository with the code or things like this. So, something that looks relevant but more generic than specific." (I8) "My EDAs [exploratory data analysis] usually create more ideas than I can reasonably fit into a single notebook, and I might decide not to share some specific feature engineering or pre-processing ideas so that I can try them out in a private model." (I10)
	(b) Attributes of "other participants"	Helpfulness of ideas and knowledge shared by others	Eisenberger et al. (1987); Kathan et al. (2015); Molm et al. (2007)	"[I]f somebody helped me then of course I would be more willing to help." (I8) "[I]f I see that someone is sharing his insights, I would also be more likely to share information with him." (I7)
	(b) Attributes of "other participants"	Previous performance of other participants	Garcia et al. (2013)	"Yes, I'll look at it [the previous performance of other participants]. So that always gives a bit of an impression as to whether it is worthwhile to deal with it [the posts in the contest discussion section] more closely or not." (I15)

	(c) Attributes of the contest	Amount of time remaining until the final idea submission deadline	Balau and Utz (2017)	“I think the less time there is, the less inclined I am to share simply due to the nature of there’s so much existing content as the clock starts to run down.” (I2) “[T]ime point really influence the contest and the contents of discussions and the Notebooks. […] In the beginning there is more some educational and data demonstration Notebooks, so it really helps to understand problem but it don’t really give some particular solutions to the problem. […] In the middle, there is more solution Notebooks and discussions where people discuss different algorithms, approaches, what can work, what won’t work. […] At the end, it’s a very bad style to post any good solutions or any good tips or any tips at the end of the contest [… it] is more about discussing […] a leaderboard score” (I6)
	(c) Attributes of the contest	Complexity of the problem	Hung (2013); Sommer et al. (2019)	“If this is something really difficult to do and only few people did this then I would maybe hesitate. If it’s a medium level of difficulty than I would share […] So, when something is difficult then I maybe would be most hesitant to share” (I8)
	(c) Attributes of the contest	Existence of rewards for sharing ideas and knowledge with others	Kaggle.com[c]; Ferrin and Dirks (2003); Ghobadi et al. (2017); Taylor (2006); Wolfe and Loraas (2008)	“I think there is a quite strong incentive because ranking points is a way of measuring your community kudos […] on Kaggle you have the upvotes, and so the community rank its own community ranking system that tells you how much you contributed.” (I2) “When I started there were only rankings for competition rankings. There were no rankings for discussions, no rankings for kernels. I think this is what—I think on Kaggle this is the reason they were doing this, to promote sharing especially on learning on early stages of competition not after it finishes but during the competition as well, like all those medals for kernels, medals for discussion.” (I8)
	(c) Attributes of the contest	Existence of rules preventing pure copying	Fernandez and Chiambaretto (2016); IDEAS.LEGO.com; Kaggle.com[d]	Talking about intellectual property when interacting in this challenge: “But this is a problem. This is a problem if you want to exchange in that type of environment. You need to create a legal environment in which you’re able to do that.” (I12)
	(c) Attributes of the contest	Main purpose of this challenge	Fehr and Fischbacher (2003)	An interviewee who participated in a Covid-19 related contest sponsored by research institutes and universities: “For me this challenge was more for a good cause and I didn’t really see it as a typical competition that I wanted to win (and honestly, I didn’t think that I had a chance). So, I just wanted to try out my ideas and share them with the community to get some feedback and see if they are useful.” (I7)
	(c) Attributes of the contest	Possibility to co-submit the idea with other participants	Kaggle.com; OpenIDEO.com	“Usually, the motivation is to find people with very high ranks in the leaderboard, but with different views than you on the same problem: so, you can combine your models with their models” (I11)
Not validated	(b) Attributes of "other participants"	Anonymity of other participants	McKenna and Green (2002)	“A nickname is enough; I wouldn’t need any personal information.” (I7)

	(b) Attributes of "other participants"	Gender of other participants	Molina et al. (2013); Vugt et al. (2007)	“No, [gender] doesn’t matter to me.” (I7)
	(c) Attributes of the contest	Brand of solution seeking organization	Bhattacharya and Sen (2003)	“I just look at the problem itself, not who is organizing it or who are the sponsor behind.” (I9)
	(c) Attributes of the contest	Visibility of the knowledge exchanged	Mihm and Schlapp (2019)	“I wouldn’t share it with a person I would share it with everyone because sharing with a person is actually called private sharing and it’s cheating. You cannot do this in Kaggle. Unless you’re in a team you cannot share things privately. If you think about that and it doesn’t matter who you share with because you share it with pretty much everybody.” (I8)
New	(a) Attributes of the focal participant	Effort it takes me to share my idea and knowledge with others	–	“So, I think maybe if the contest is hard enough, if we are talking about some kind of computer vision where you have to dive into deep learning or maybe even connected with some generative tasks, there will be less Notebooks because to make any solution it needs more time. If we are talking about a table contest where you have some machine learning libraries where you need apply three lines of codes and you will get your submission file, there will be more Notebooks. So, I think if preparing your submission is less time consuming there will be more Notebooks, but the qualities of these Notebooks can be really low.” (I6) [b]
	(a) Attributes of the focal participant	Effort it takes me to incorporate ideas and knowledge from others	–	“[Y]ou can’t look through all the Notebooks, so I try to look at the people that had some experience in Kaggle and skills […], so I think I try to prioritize people that were good at Kaggle” (I1)
	(a) Attributes of the focal participant	My performance in previous challenges	–	“But I’m a beginner in Kaggle, I haven’t won anything, or I don’t have extensive experience, so […] I might as well share. I’m not going to really lose anything.” (I1)
	(b) Attributes of "other participants"	Similarity of ideas and knowledge shared with me compared to my own	–	„[I]f you can filter something that is similar to your project or could have leverage for your project then you’re more likely to be able to give constructive feedback and they’re able to then give you constructive feedback or questions“ (I13)
Used as control variable in ex-post treatment survey	(b) Attributes of "other participants"	My trust in other participants	Jarvenpaa and Leidner (1999)	“But if I feel that someone only tries to get some insights from me for his own personal advantage, I wouldn’t share too much information.” (I7) “I’m completely new to Kaggle and I cannot trust everyone. What if my model works perfectly? I cannot share it, right?” (I3)

To give participants a reference value for the prize(s), we keep this constant in the scenario	(c) Attributes of the contest	Number of participants	Boudreau et al. (2016); Körpeoğlu and Cho (2018); Terwiesch and Xu (2008)	"So, number of participants really influenced because it's motivation of people to make this, to perform, to spend their time for making good Notebooks and for bigger amount of people to see them or prepare better discussions and bigger amount of people can see them." (I6)

Notes.

[a] After asking interviewees open-ended questions on what drives their decision to cooperate with other contestants, we presented them with a list of all of our attributes derived from the literature and discussed each attribute. If interviewees assessed an attribute as being a) relevant we indicate it here as *validated* or b) not relevant we indicate it as *not validated*. In addition, c) if an attribute had previously not been in the list but mentioned as being relevant by interviewees either in the open-ended question or during the remaining interview, we added it in our list and indicate it as *new*.

[b] Notebooks on Kaggle are a "a cloud computational environment that enables reproducible and collaborative analysis". These are scripts containing code that participants can share with each other in contests (https://www.kaggle.com/docs/notebooks).

[c] Kaggle offers a public ranking with medals for sharing code notebooks, topics, or comments with other participants (for more information see the notebook and discussion medals discussion on https://www.kaggle.com/progression).

[d] The crowdsourcing contests by LEGO IDEAS states that "If someone has directly stolen your creation or original concept and uploaded it as their own, you may report their product idea for plagiarism using the report link on the product idea" (see https://ideas.lego.com/guidelines). In a similar vein, Kaggle also has rules that prevent the simple copying of code without appropriate referencing (see https://www.kaggle.com/getting-started/227919).

Table 13: Study 2 sample descriptives, randomization checks, and manipulation check

	No competition		**Low competition**		**High competition**		**Equal distribution across experimental groups**	
Variables[a]	Mean	SD	Mean	SD	Mean	SD	Test[b]	p-value
Age	26.554	7.842	27.605	9.122	27.688	8.694	Kruskal-Wallis	0.576
Agreeableness	0.893	0.655	0.873	0.624	0.912	0.627	Kruskal-Wallis	0.793
Altruism	5.281	1.109	5.388	1.019	5.439	1.013	Kruskal-Wallis	0.487
Crowdsourcing experience[c]	1.344	0.560	1.384	0.586	1.387	0.616	Chi-squared	0.487
Education[d]	3.763	0.784	3.721	0.750	3.909	0.790	Chi-squared	0.487
Extroversion	0.636	0.826	0.498	0.773	0.535	0.757	Kruskal-Wallis	0.230
Gender (1=female)	0.409	0.493	0.426	0.496	0.392	0.490	Chi-squared	0.230
Openness	2.244	0.652	2.204	0.589	2.299	0.619	Kruskal-Wallis	0.392
Perceived competition[e]	3.482	1.754	5.212	1.184	6.013	0.808	Kruskal-Wallis	0.000
Reciprocity: Creditor ideology	4.683	1.347	4.782	1.194	4.827	1.274	Kruskal-Wallis	0.549
Reciprocity: Reciprocation wariness	3.325	1.018	3.292	1.032	3.277	0.985	ANOVA	0.895
Self-efficacy	5.009	1.146	5.016	1.035	5.171	1.077	Kruskal-Wallis	0.185
Trait competitiveness	4.876	1.153	5.166	0.998	5.050	1.111	Kruskal-Wallis	0.050
Trust	4.396	1.280	4.504	1.288	4.358	1.366	Kruskal-Wallis	0.450
Observations[f]	186		190		186			

Notes.
[a] See Appendix 6 for constructs, items, scales, and scale reliabilities and Appendix 25 for a pairwise correlation table.
[b] All variables were asked ex-post to the scenario task. Except for reciprocity: reciprocation wariness, all continuous variables are not normally distributed. Hence, we use analysis of variance tests (ANOVA) for the former and non-parametric Kruskal-Wallis equality-of-populations rank tests (K-W) for the latter variables. For categorical variables we use Pearson's chi-squared tests (Chi-2).
[c] Crowdsourcing experience scale: 1 = Never, 2 = 1-3 times, 3 = More than 3 times.
[d] Education scale: 3 = High school or lower level, 4 = Bachelor's or equivalent level, 5 = Master's or higher level.
[e] Perceived competition represents our manipulation check for the competition across the scenarios. This means that a p-value < 0.05 indicates that our treatments had the intended effect of inducing different levels of competition.
[f] We excluded 70 participants from our sample that failed to recall the competition prize in the scenario or that, on average, stayed less than ten seconds on the ACBC situation decision pages.

Table 14: Number of times an attribute was selected as being among the five most important attributes influencing the decision to exchange ideas and knowledge in the three competition groups and where the frequencies of selection differ significantly across competition groups

	Selected as one of the five most important attributes	**Frequency**	**Experimental group**			**Total**	**Test for equal distribution**	
			No comp.	Low comp.	High comp.		Test	p-value
Copying rules	Not selected	Frequency	88	63	59	210	Chi-2	0.003
		Expected frequency	*69.502*	*70.996*	*69.502*			
	Selected	Frequency	98	127	127	352		
		Expected frequency	*116.498*	*119.004*	*116.498*			
Effort to share	Not selected	Frequency	114	147	143	404	Chi-2	0.000
		Expected frequency	*133.708*	*136.584*	*133.708*			
	Selected	Frequency	72	43	43	158		
		Expected frequency	*52.292*	*53.416*	*52.292*			
Effort to incorporate	Not selected	Frequency	127	150	135	412	Chi-2	0.063
		Expected frequency	*136.356*	*139.288*	*136.356*			
	Selected	Frequency	59	40	51	150		
		Expected frequency	*49.644*	*50.712*	*49.644*			
My personal knowledge and skills that enable me to win	Not selected	Frequency	150	121	120	391	Chi-2	0.000
		Expected frequency	*129.406*	*132.189*	*129.406*			
	Selected	Frequency	36	69	66	171		
		Expected frequency	*56.594*	*57.811*	*56.594*			

Note. This table only list those four attributes for which the Chi-squared test for equal distribution across experimental groups has a p-value of $p<0.1$, i.e., attributes that significantly differ in their selection frequency across the three competitive conditions. The eleven attributes not listed here do not significantly differ in their distribution across competition groups.

Table 15: List of attributes and their importance weights as well as attribute levels and their utilities across competition groups

Category	Attribute	Attribute importance weights (mean, in %) No comp.	Low comp.	High comp.	Attribute levels	Attribute utilities (mean) No comp.	Low comp.	High comp.
(a) Attributes of focal participant	My main motivation to participate in the challenge	9.40	8.26	8.89	• Fun/Learning	16.56	20.69	28.75
					• My interest in the topic of the idea generation challenge	8.91	16.52	20.95
					• Winning a prize	-19.48	-32.38	-34.72
					• Gaining career benefits from submitting one of the best ideas	-5.99	-4.82	-14.98
	My personal knowledge and skills that enable me to win	2.29	5.69	5.85	• I have all relevant knowledge and skills	3.8	-12.27	-17.75
					• I have little relevant knowledge or skills	-3.8	12.27	17.75
	Effort it takes me to share my idea and knowledge with others	6.31	4.26	3.65	• Considerable effort	-46.89	-27.93	-20.30
					• Moderate effort	9.13	6.38	2.35
					• Little effort	37.76	21.55	17.95
	Type of knowledge I can share with others	7.17	4.32	3.77	• My entire initial idea	-29.72	-12.39	-14.20
					• Selected parts of my initial idea	20.68	17.44	13.72
					• Up- / downvotes on other's ideas	-2.23	-6.51	-5.34
					• Specific comments on others' ideas	11.27	1.47	5.83
	Effort it takes me to incorporate ideas and knowledge from others	5.08	3.53	4.16	• Considerable effort	-33.45	-22.01	-21.90
					• Moderate effort	4.14	5.89	7.05
					• Little effort	29.30	16.12	14.85
	My performance in previous challenges	2.40	2.86	1.62	• Top-performing	-10.59	-4.07	-4.90
					• Average-performing	1.47	2.83	-0.31
					• Low-performing	9.11	1.24	5.21
(b) Attributes of "other participants"	Helpfulness of ideas and knowledge shared by others	9.75	11.30	9.93	• Much helpful knowledge	63.25	74.83	68.59
					• Some helpful knowledge	12.28	9.67	9.91
					• Little helpful knowledge	-76.53	-84.50	-78.50
	Previous performance of other participants	2.79	4.70	3.90	• Top-performing participants	15.06	23.50	24.07
					• Average-performing participants	4.25	8.30	2.33
					• Low-performing participants	-19.30	-31.8	-26.39
	Similarity of ideas and knowledge shared with me compared to my own	3.64	2.92	2.60	• Similar	0.98	-0.04	-5.15
					• Different but complementary	11.85	10.84	11.40
					• Different but not complementary	-12.83	-10.80	-6.25
(c) Attributes of the contest	Existence of rules preventing pure copying	13.81	20.10	23.17	• No such rules exist	-92.43	-144.86	-170.58
					• Such rules exist	92.43	144.86	170.58
	Existence of rewards for sharing ideas and knowledge with others	12.40	12.04	9.67	• No such rewards exist	-92.60	-78.68	-70.54
					• Such rewards exist	92.60	78.68	70.54
	Complexity of the problem	6.80	6.76	6.91	• Low	-23.17	-33.79	-37.01
					• Medium	12.98	12.19	4.32
					• High	10.19	21.60	32.69
	Amount of time remaining until the final idea submission deadline	9.50	5.81	6.18	• A few hours	-40.11	-36.91	-24.00
					• A few days	18.59	10.17	11.48
					• A few weeks	21.52	26.74	12.52
	Main purpose of this challenge	3.83	3.84	4.74	• Serves primarily a social purpose	23.86	21.87	25.66
					• Serves primarily a commercial purpose	-23.86	-21.87	-25.66
	Possibility to co-submit the idea with other participants	4.82	3.61	4.97	• I can co-submit with others	35.73	25.76	34.21
					• I cannot co-submit with others	-35.73	-25.76	-34.21

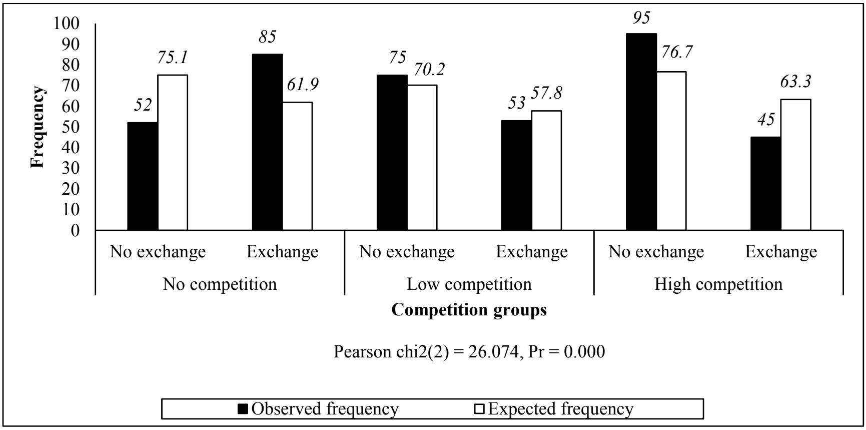
Table 16: Cluster descriptions across competitive conditions

	No competition			Low competition		High competition	
	Cluster N1	Cluster N2	Cluster N3	Cluster L1	Cluster L2	Cluster H1	Cluster H2
Interpretation	Misappropriation hazards focused	Extrinsically motivated	Intrinsically motivated	Misappropriation hazards focused	Extrinsically motivated	Misappropriation hazards focused	Intrinsically motivated
Most important attributes	Copying rules (36.55%) Helpfulness (11.81%)	Sharing rewards (24.20%) Helpfulness (12.54%) Effort to share (12.44%)	Motivation (15.13%) Time remaining (14.19%) Type of knowledge (12.19%) Complexity (10.06%)	Copying rules (38.75%) Helpfulness (12.00%)	Sharing rewards (15.01%) Motivation (11.86%) Helpfulness (10.80%)	Copying rules (42.13%)	Motivation (12.29%) Helpfulness (11.05%)
Other important attributes	Sharing rewards (9.56%)	Time remaining (8.75%) Motivation (7.24%) Effort to incorporate (6.85%)		Sharing rewards (7.86%)	Complexity (8.00%) Skills and knowledge (7.24%) Copying rules (6.83%)	Sharing rewards (9.71%) Helpfulness (8.57%)	Sharing rewards (9.63%) Skills and knowledge (9.12%) Time remaining (7.99%) Complexity (7.75%) Copying rules (7.56%) Purpose (6.71%)
# of relevant attributes [a]	3	6	4	3	6	3	9
The 3 most valued attribute levels	Such rules exist (274.11) Much helpful knowledge (76.28) Such rewards exist (71.28)	Such rewards exist (181.48) Much helpful knowledge (87.09) Little effort (84.50)	Fun/Learning (55.53) Selected parts of my initial idea (49.34) Interest in topic (43.61)	Such rules exist (290.64) None (153.57) Much helpful knowledge (83.41)	Such rewards exist (92.90) Much helpful knowledge (68.72) None (48.89)	Such rules exist (315.96) None (147.20) Much helpful knowledge (58.6)	Such rewards exist (70.41) Much helpful knowledge (76.81) Fun/Learning (56.48)
The 3 least valued attribute levels	No such rules exist (-274.11) Little helpful knowledge (-93.24) No such rewards exist (-71.28)	No such rewards exist (-181.48) Little helpful knowledge (-100.60) Considerable effort [to share] (-98.92)	My entire initial idea (-68.76) Winning a prize (-54.20) Low complexity (-46.85)	No such rules exist (-290.64) Little helpful knowledge (-91.75) No such rewards exist (-58.70)	No such rewards exist (-92.90) Little helpful knowledge (-79.34) Winning a prize (-47.20)	No such rules exist (-315.96) No such rewards exist (-70.07) Little helpful knowledge (-70.01)	Little helpful knowledge (-85.49) No such rewards exist (-70.41) Winning a prize (-62.56)
Observations	53	68	65	111	79	102	84

Notes. The reproducibility of the cluster solutions is 78.40% (no competition), 96.80% (low competition), and 98.20% (high competition), respectively. [a] In the case that all attributes were equally important, each attribute would contribute 6.67% (=100% / 15 attributes). The number of relevant attributes row includes all attributes that exceed this average contribution level of 6.67%. [b] None represents the value of a no choice option and is not included in the interpretations.

Figures

Figure 6: "No exchange vs. exchange idea and knowledge" across the competition groups.



Note. The values above the bars indicate the respective frequencies of the cooperation decisions for this sub-group. For example, in the non-competitive group 75.1 participants were expected to not share their idea and knowledge, but our experimental data shows that significantly less (52 participants) decided to not do so.

Figure 7: Overview of the process in Study 2

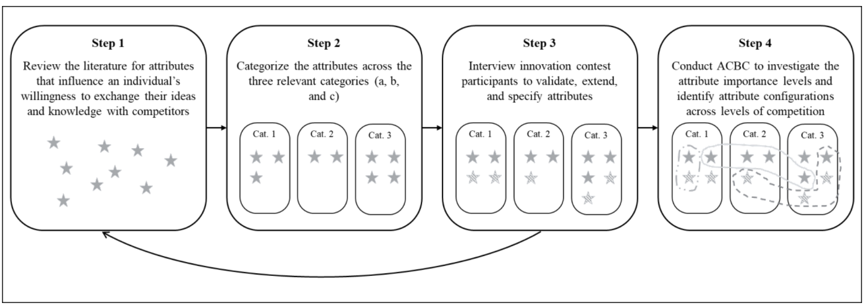


Figure 8: Summary of the individual factors whose importance weights in relation to the decision to cooperate (or not) steadily increase or decrease when competition increases

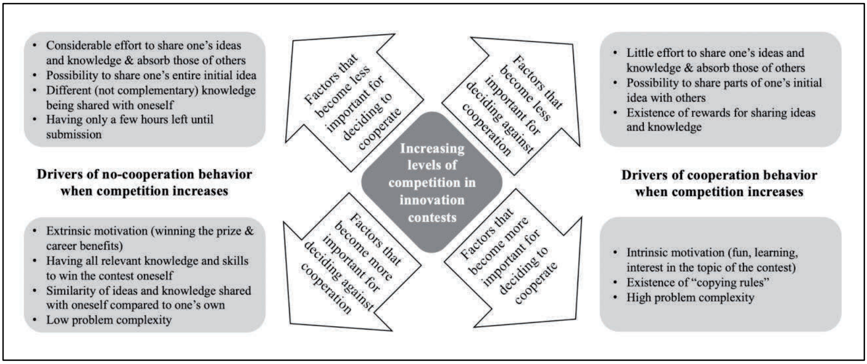


Figure 9: Graphical summary of ensemble cluster analysis results (by competitive condition)

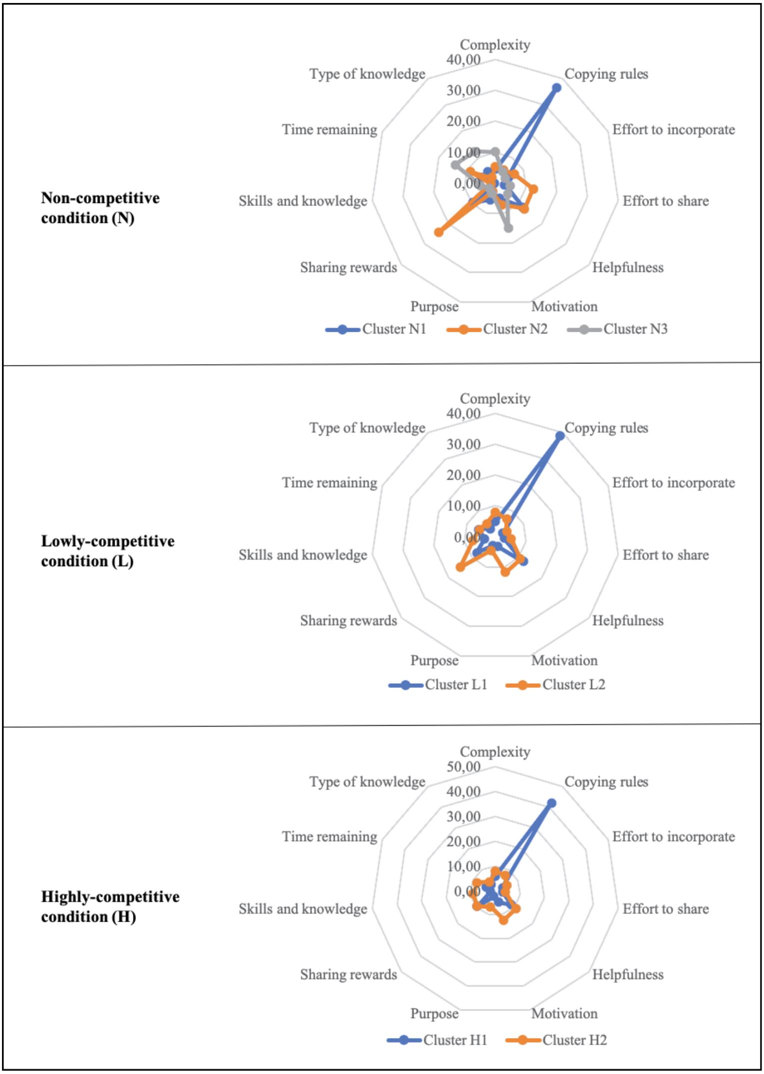


Figure 10: Graphical summary of ensemble cluster analysis results (by cluster type across competitive conditions)

2.10. Appendix

Appendix 6: Study 1: Constructs, items, scales, and reliabilities

Construct	Items and scales	Scale reliabilities (Cronbach's Alpha) Study 1	Study 2	Source
Agreeableness	1. Tends to find faults with others [reverse-scored] 2. Is helpful and unselfish with others 3. Starts quarrels with others [reverse-scored] 4. Has a forgiving nature 5. Is generally trusting 6. Can be cold and aloof [reverse-scored] 7. Is considerate and kind to almost everyone 8. Is sometimes rude to others [reverse-scored] 9. Likes to cooperate with others [5-point Likert-type scale][a]	0.736	0.764	John and Srivastava (1999)
Altruism	1. I am helping others even though it is not required. 2. I am always ready to help or to lend a helping hand to those around me. 3. I am willing to give my time to help others. [7-point Likert-type scale][b]	0.850	0.860	Adapted from MacKenzie et al. (1993)
Crowdsourcing experience	How often have you participated in real-world idea generation challenges similar to the scenario you read before? 1. Never 2. 1-3 times 3. More than 3 times [Single-choice]	N/A	N/A	Adapted from Franke et al. (2013)
Extroversion	1. Is talkative 2. Is reserved [reverse-scored] 3. Is full of energy 4. Generates a lot of enthusiasm 5. Tends to be quiet [reverse-scored] 6. Has an assertive personality 7. Is sometimes shy, inhibited [reverse-scored] 8. Is outgoing, sociable [5-point Likert-type scale]	0.853	0.840	John and Srivastava (1999)
Factual prize recollection	In the scenario you just read what was (were) the potential prize(s) for the participants? Please select the option you think is correct. 1. The idea that gets most likes on Facebook wins a prize. 2. 500 randomly selected ideas win 100€ each. 3. The 500 best ideas win 100€ each. 4. The best idea wins 50000€. 5. There is no prize mentioned in the scenario. 6. The 10 best ideas win 5000€ each. [Single-choice]	N/A	N/A	N/A

Openness	1. Is original, comes up with new ideas 2. Is curious about many different things 3. Has an active imagination 4. Is inventive 5. Values artistic, aesthetic experiences 6. Prefers work that is routine [reverse-scored] 7. Likes to reflect, play with ideas 8. Has few artistic interests [reverse-scored] 9. Is sophisticated in art, music, or literature [5-point Likert-type scale]	0.756	0.743	John and Srivastava (1999)
Perceived competition	1. The amount of prize money creates quite a bit of competition between the individuals that participate in the idea generation challenge described in the scenario. 2. The number of prizes creates quite a bit of competition between the individuals that participate in the idea generation challenge described in the scenario. 3. The idea generation challenge from the scenario creates a good deal of competition about who produces the best idea. [7-point Likert-type scale]	0.852	0.864	Adapted from Baer et al. (2010)
Reciprocity: Creditor ideology	1. If someone does something for you, you should do something of greater value for them. 2. If someone does you a favor, you should do even more in return. 3. If someone goes out of their way to help me, I feel as though I should do more for them than merely return the favor. 4. If a person does you a favor, it's a good idea to repay that person with a greater favor. [7-point Likert-type scale]	0.867	0.922	Adapted from Eisenberger et al. (1987)
Reciprocity: Reciprocation wariness	1. It generally pays to let others do more for you than you do for them. 2. In the long run, it's better to accept favors than to do favors for others. 3. You shouldn't offer to help someone if they don't ask for your help. 4. You should not bend over to backwards to help another person. [7-point Likert-type scale]	0.600	0.690	Adapted from Eisenberger et al. (1987)
Self-efficacy	9. I will be able to achieve most of the goals that I have set for myself. 10. When facing difficult tasks, I am certain that I will accomplish them. 11. In general, I think that I can obtain outcomes that are important to me. 12. I believe I can succeed at most any endeavor to which I set my mind. 13. I will be able to successfully overcome many challenges. 14. I am confident that I can perform effectively on many different tasks. 15. Compared to other people, I can do most tasks very well. 8. Even when things are tough, I can perform quite well. [7-point Likert-type scale]	0.929	0.934	Chen et al. (2001)

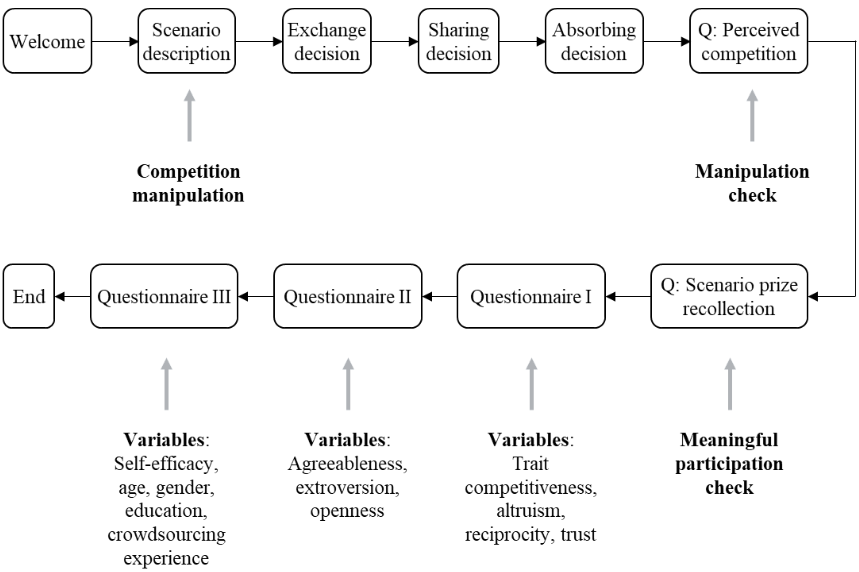
Trait competitiveness	1. I enjoy working in situations involving competition with others. 2. It is important to me to perform better than others on a task. 3. I feel that winning is important in both work and games. 4. I try harder when I am in competition with other people. [7-point Likert-type scale]	0.811	0.786	Brown et al. (1998)
Trust	1. I generally have faith in humanity. 2. I feel that people are generally reliable. 3. I generally trust other people unless they give me reason not to. [7-point Likert-type scale]	0.824	0.850	Ridings et al. (2002)

Notes.

[a] The 7-point Likert-type scale ranges from 1=strongly disagree, 2=disagree, 3=somewhat disagree, 4=neither agree or disagree, 5=somewhat agree, 6=agree, to 7=strongly agree

[b] The 5-point Likert-type scale ranges from 1=disagree strongly, 2=disagree a little, 3=neither agree nor disagree, 4=agree a little, 5=agree strongly.

Appendix 7: Study 1: Overview of the experimental procedure



Appendix 8: Study 1 and 2: Scenario instructions and description

You will now read a scenario. We ask you to empathize with the situation and project your thoughts into it, as if you were really in the scenario. Please take enough time to carefully read it, as you will be asked questions about it afterwards.

The button to go to the next page will appear after 1.5 minutes.

Scenario

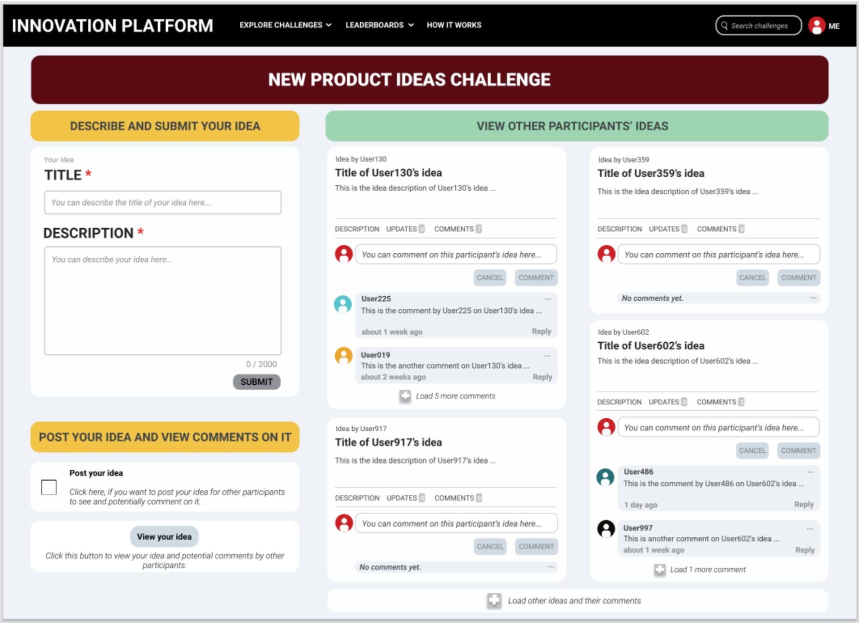
[All groups]
You have decided to participate in an online idea generation challenge on an innovation platform, because you have an idea to contribute with (the picture below shows a schematic representation of the platform surface). The challenge is hosted by a company that is currently searching for new product ideas to extend its existing product lines. In the challenge, participants are asked to generate ideas for potential new products. In previous idea generation challenges of the company, around 1000 participants would usually participate.

[No competition]
As a reward, the company gives all challenge participants a 50€ online shopping gift card. This means that 1000 out of 1000 participants will receive a prize. Your chance to win a prize does not depend on the quality of your idea compared to the other ideas. As idea submissions are not ranked and all participants receive a prize, the challenge does not take place in a competitive environment.

[Low competition]
As a reward, the company offers 500 x 100€ cash prizes for the 500 best ideas in the challenge. This means that 500 out of 1000 participants will win a prize. Your chance to win a prize depends on the quality of your idea being better than 50% of the other ideas. The way the ideas are evaluated and the number of prizes available indicate that the challenge takes place in a lowly competitive environment.

[High competition]
As a reward, the company offers a 1 x 50.000 € cash prize for the single best idea in the challenge. This means that 1 out of 1000 participants will win a prize. Your chance to win the prize depends on the quality of your idea being better than all of the other ideas. The way the ideas are evaluated and the number of prizes available indicate that the challenge takes place in a highly competitive environment.

[All groups]
Before you submit your final idea, you have the possibility to exchange your idea and knowledge with other participants. You can post your own idea and potentially receive comments from other participants. You can also give feedback comments on some of the other participants' ideas. Regardless of your decision to exchange (or not), you can revise and then submit your final idea at the end.



INNOVATION PLATFORM
EXPLORE CHALLENGES
LEADERBOARDS
HOW IT WORKS
Search challenges
ME
NEW PRODUCT IDEAS CHALLENGE
DESCRIBE AND SUBMIT YOUR IDEA
VIEW OTHER PARTICIPANTS' IDEAS
Your idea
TITLE *
You can describe the title of your idea here...
DESCRIPTION *
You can describe your idea here...
0 / 2000
SUBMIT
POST YOUR IDEA AND VIEW COMMENTS ON IT
Post your idea
Click here, if you want to post your idea for other participants to see and potentially comment on it.
View your idea
Click this button to view your idea and potential comments by other participants.
Idea by User130
Title of User130's idea
This is the idea description of User130's idea ...
DESCRIPTION UPDATES COMMENTS
You can comment on this participant's idea here...
CANCEL COMMENT
User225
This is the comment by User225 on User130's idea ...
about 1 week ago Reply
User019
This is the another comment on User130's idea ...
about 2 weeks ago Reply
Load 5 more comments
Idea by User917
Title of User917's idea
This is the idea description of User917's idea ...
No comments yet.
Idea by User359
Title of User359's idea
This is the idea description of User359's idea ...
No comments yet.
Idea by User602
Title of User602's idea
This is the idea description of User602's idea ...
User486
This is the comment by User486 on User602's idea ...
1 day ago Reply
User997
This is another comment on User602's idea ...
about 1 week ago Reply
Load 1 more comment
Load other ideas and their comments

Appendix 9: Study 1: Pairwise correlation table

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Exchange idea and knowledge	1.00										
(2) Sharing (index)	0.61***	1.00									
(3) Absorbing (index)	0.23***	0.40***	1.00								
(4) Post own idea	0.69***	0.85***	0.36***	1.00							
(5) Give feedback	0.32***	0.83***	0.31***	0.41***	1.00						
(6) Absorb Ideas	0.15**	0.25***	0.86***	0.24***	0.17***	1.00					
(7) Absorb Feedback	0.24***	0.43***	0.79***	0.36***	0.35***	0.37***	1.00				
(8) Agreeableness	0.13**	0.26***	0.14**	0.18***	0.26***	0.09^{+}	0.14**	1.00			
(9) Altruism	0.16**	0.30***	0.12*	0.18***	0.33***	0.03	0.19***	0.52***	1.00		
(10) Extroversion	-0.03	0.04	0.00	0.01	0.05	0.05	-0.06	0.24***	0.25***	1.00	
(11) Openness	0.07	0.06	0.05	0.05	0.06	-0.01	0.10*	0.23***	0.23***	0.25***	1.00
(12) Perceived competition	-0.20***	-0.22***	-0.00	-0.29***	-0.07	0.04	-0.05	-0.02	0.02	0.09^{+}	-0.06
(13) Rec.: Creditor ideology	0.08	0.09^{+}	0.03	0.03	0.12*	0.04	0.01	0.20***	0.19***	0.01	0.04
(14) Rec.: Reciprocation wariness	-0.08^{+}	-0.15**	-0.10*	-0.15**	-0.10*	0.00	-0.18***	-0.34***	-0.42***	-0.02	-0.09^{+}
(15) Trait competitiveness	-0.08	-0.03	0.07	-0.07	0.02	0.11*	-0.01	-0.05	-0.02	0.36***	0.09^{+}
(16) Trust	0.16**	0.22***	0.16**	0.19***	0.19***	0.12*	0.14**	0.47***	0.29***	0.23***	0.07
(17) Self-efficacy	-0.05	-0.01	0.06	-0.03	0.03	0.06	0.03	0.20***	0.22***	0.50***	0.26***
(18) Age (log.)	0.01	-0.03	-0.05	-0.04	-0.00	-0.06	-0.03	0.13**	0.00	-0.05	0.05
(19) Crowdsourcing experience	0.04	0.04	0.03	0.03	0.04	0.06	-0.01	0.08	0.08	0.16**	0.08
(20) Education	-0.00	0.07	0.02	0.05	0.06	0.06	-0.03	0.17***	0.08^{+}	0.08	0.02
(21) Gender (1 = female)	-0.03	-0.07	-0.00	-0.02	-0.11*	0.04	-0.06	-0.04	-0.13**	-0.12*	-0.05

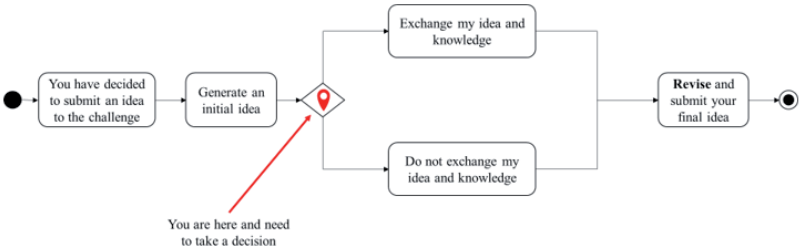
	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
(12) Perceived competition	1.00									
(13) Rec.: Creditor ideology	0.17***	1.00								
(14) Rec.: Reciprocation wariness	0.03	-0.01	1.00							
(15) Trait competitiveness	0.16**	0.22***	0.14**	1.00						
(16) Trust	-0.04	0.15**	-0.15**	0.01	1.00					
(17) Self-efficacy	0.06	0.09^{+}	-0.00	0.32***	0.21***	1.00				
(18) Age (log.)	-0.01	-0.03	-0.12*	-0.23***	0.05	-0.02	1.00			
(19) Crowdsourcing experience	0.06	0.03	-0.04	0.09^{+}	0.10*	0.19***	-0.04	1.00		
(20) Education	-0.04	0.03	-0.07	-0.05	0.12*	0.07	0.36***	0.12*	1.00	
(21) Gender (1 = female)	0.02	0.11*	0.09^{+}	0.10*	-0.03	-0.04	-0.07	-0.00	-0.14**	1.00

Notes. Observations: 405. $^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Appendix 10: Study 1: Scenario decision text for “exchanging my idea and knowledge” (screenshot of page 3 in the survey)

The scenario decision

Please try to imagine vividly that you find yourself in the previously described situation and answer the following questions accordingly. Remember that you have already decided to participate in the challenge and submit an idea. You are currently at the following step in the challenge as visualized in the figure below:



In the previously described scenario, would you exchange your idea and knowledge with other participants?

- ◯ No, I would not exchange my idea and knowledge
- ◯ Yes, I would exchange my idea and knowledge

Display scenario again

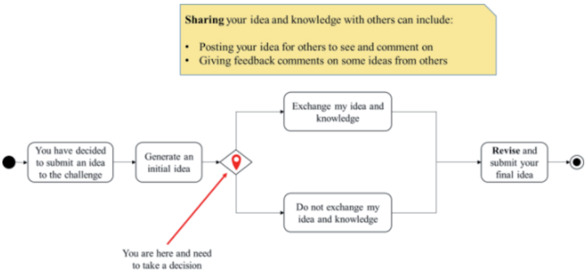
Display schematic representation of platform again

Next

Appendix 11: Study 1: Scenario decision text for “sharing your idea and knowledge” (screenshot of page 4 in the survey)

Other scenario decisions

In addition to your general decision to exchange your idea and knowledge with others (or not), please let us know how likely you are to use the specific possibilities for sharing your idea and knowledge with other participants.



1. How likely is it that you would <u>post your idea</u> for other participants to see and comment on it?

very unlikely 1 2 3 4 5 6 7 very likely

Please briefly explain your choice in your own words in 1-2 sentences:

2. How likely is it that you would <u>give feedback</u> comments on some of the ideas of other participants?

very unlikely 1 2 3 4 5 6 7 very likely

Please briefly explain your choice in your own words in 1-2 sentences:

Display scenario again

Display schematic representation of platform again

Next

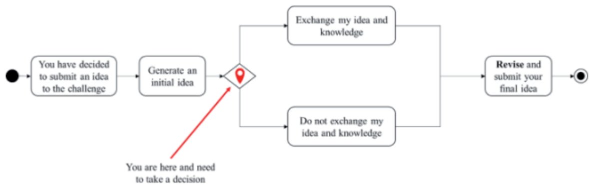
Appendix 12: Study 1: Scenario decision text for “absorbing ideas and knowledge” (screenshot of page 5 in the survey)

Other scenario decisions

Now, please also let us know how likely you are to use the specific possibilities for incorporating ideas and knowledge from other participants.

Incorporating ideas and knowledge from others can include:

- Incorporating knowledge from initial ideas others shared
- Incorporating knowledge from feedback comments others provided on your own initial idea



3. If knowledge from some of the other ideas you saw was helpful, how likely is it that you would incorporate this knowledge into your own idea?

very unlikely 1 2 3 4 5 6 7 very likely

Please briefly explain your choice in your own words in 1-2 sentences:

4. Provided that you shared your idea with others and some of the feedback comments you received were helpful, how likely is it that you would incorporate knowledge from these comments into your own idea?

very unlikely 1 2 3 4 5 6 7 very likely

Please briefly explain your choice in your own words in 1-2 sentences:

Display scenario again

Display schematic representation of platform again

Next

Appendix 13: Study 1: Experiment results for equal sample sizes across competition groups

VARIABLES	**Exchange idea and knowledge (n/y)**		**Sharing likelihood**		**Absorbing likelihood**	
	Probit		OLS		OLS	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Low competition	-0.495**	-0.504**	-1.133**	-1.099**	0.586+	0.636+
	(0.158)	(0.167)	(0.379)	(0.363)	(0.325)	(0.327)
High competition	-0.701***	-0.752***	-1.719***	-1.679***	-0.211	-0.066
	(0.160)	(0.169)	(0.379)	(0.363)	(0.325)	(0.328)
Agreeableness		-0.019		0.432		0.355
		(0.153)		(0.329)		(0.297)
Altruism		0.197*		0.772***		0.144
		(0.089)		(0.192)		(0.173)
Extroversion		-0.063		-0.065		-0.415*
		(0.108)		(0.228)		(0.206)
Openness		0.153		-0.104		-0.030
		(0.124)		(0.266)		(0.240)
Reciprocity: Creditor ideology		0.134*		0.158		-0.110
		(0.068)		(0.143)		(0.129)
Reciprocity: Reciprocation wariness		0.031		-0.011		-0.266
		(0.086)		(0.187)		(0.168)
Trait competitiveness		-0.091		0.030		0.271+
		(0.072)		(0.155)		(0.140)
Trust		0.186**		0.349*		0.269*
		(0.065)		(0.135)		(0.122)
Self-efficacy		-0.152+		-0.344+		0.065
		(0.081)		(0.176)		(0.158)
Age (log.)		0.005		-0.616		-0.519
		(0.277)		(0.603)		(0.544)
Crowdsourcing experience (1-3 times)		0.119		0.128		0.033
		(0.158)		(0.339)		(0.305)
Crowdsourcing experience (> 3 times)		0.354		0.237		0.282
		(0.349)		(0.772)		(0.696)
Education (Bachelor's or equivalent)		-0.187		-0.044		-0.153
		(0.158)		(0.341)		(0.307)
Education (Master's or higher)		-0.181		0.216		0.262
		(0.205)		(0.446)		(0.402)
Gender (1 = female)		-0.130		-0.344		-0.008
		(0.141)		(0.305)		(0.275)
Constant	0.278*	-1.288	8.719***	5.970*	10.398***	9.769***
	(0.112)	(1.248)	(0.268)	(2.722)	(0.230)	(2.454)
Observations	384	384	384	384	384	384
Pseudo R2	0.039	0.106				
LR chi2	20.63	56.18				
Prob > chi2	0.004	0.000				
R-squared			0.053	0.201	0.017	0.084
F-statistic			10.629	5.415	3.225	1.981
Prob > F			0.000	0.000	0.041	0.012

Notes. Coefficients are shown. Standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. We used Stata's "sample" command to pseudorandomly drop observations in the low and high competition group until all groups had an equal sample size of 128 (i.e., the sample size of the low competition group).

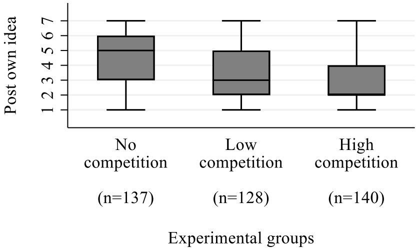
Appendix 14: Study 1: Experiment results for the full sample without dropping any observations

VARIABLES	Exchange idea and knowledge (n/y)		Sharing likelihood		Absorbing likelihood	
	Probit		OLS		OLS	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Low competition	-0.490***	-0.481**	-1.296***	-1.230***	0.451	0.483
	(0.147)	(0.153)	(0.350)	(0.336)	(0.303)	(0.305)
High competition	-0.695***	-0.730***	-1.788***	-1.757***	-0.287	-0.192
	(0.146)	(0.152)	(0.342)	(0.330)	(0.297)	(0.300)
Agreeableness		0.049		0.452		0.252
		(0.138)		(0.301)		(0.273)
Altruism		0.189*		0.705***		0.223
		(0.081)		(0.175)		(0.159)
Extroversion		-0.046		0.114		-0.298
		(0.095)		(0.205)		(0.186)
Openness		0.132		-0.105		0.075
		(0.113)		(0.245)		(0.222)
Reciprocity: Creditor ideology		0.093		0.086		-0.090
		(0.061)		(0.132)		(0.119)
Reciprocity: Reciprocation wariness		0.002		-0.070		-0.220
		(0.076)		(0.166)		(0.150)
Trait competitiveness		-0.090		-0.052		0.250+
		(0.065)		(0.142)		(0.129)
Trust		0.136*		0.304*		0.219+
		(0.058)		(0.125)		(0.113)
Self-efficacy		-0.120		-0.273+		0.042
		(0.075)		(0.164)		(0.149)
Age (log.)		0.053		-0.325		-0.352
		(0.254)		(0.555)		(0.503)
Crowdsourcing experience (1-3 times)		0.149		0.053		-0.036
		(0.144)		(0.313)		(0.284)
Crowdsourcing experience (> 3 times)		0.310		0.153		0.389
		(0.316)		(0.707)		(0.641)
Education (Bachelor's or equivalent)		-0.107		0.082		-0.134
		(0.143)		(0.312)		(0.283)
Education (Master's or higher)		-0.190		0.251		0.170
		(0.187)		(0.407)		(0.369)
Gender (1 = female)		-0.121		-0.292		0.047
		(0.130)		(0.284)		(0.257)
Constant	0.277**	-1.132	8.853***	6.110*	10.436***	8.862***
	(0.102)	(1.108)	(0.241)	(2.433)	(0.209)	(2.207)
Observations	452	452	452	452	452	452
Pseudo R2	0.039	0.094				
LR chi2	24.53	58.85				
Prob > chi2	0.000	0.000				
R-squared			0.061	0.188	0.013	0.069
F-statistic			14.520	5.918	2.972	1.879
Prob > F			0.000	0.000	0.052	0.018

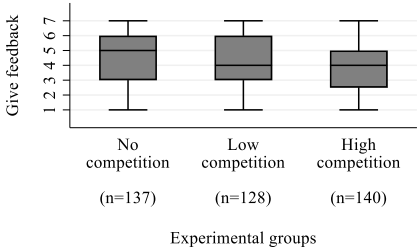
Notes. Coefficients are shown. Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Appendix 15: Study 1: Box plots for each sharing and absorbing variable over the competition groups.

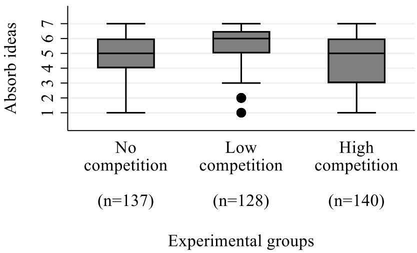
(a) Sharing knowledge: post own ideas



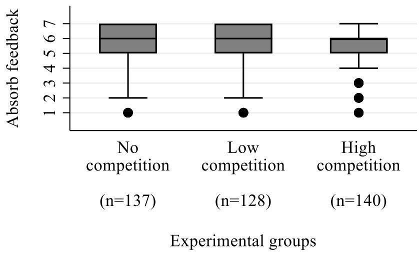
(b) Sharing knowledge: give feedback



(c) Absorbing knowledge: absorb ideas



(d) Absorbing knowledge: absorb feedback



Notes. Graphs show the box plots for the respective sharing (i.e., (a) post own idea and (b) give feedback) or absorbing (i.e., (c) absorb ideas and (d) absorb feedback) decision variables over each competition group. The thick black line in each box represents the median, while the box's lower and upper hinge indicate the 25th and 75th percentile, respectively. Whiskers and their adjacent lines represent the upper and lower adjacent values, black dots the outside values.

Appendix 16: Study 1: Mean values and equal distribution tests for each sharing and absorbing variable over the competition groups.

Variables	**No competition**		**Low competition**		**High competition**		**Equal distribution across groups**		
	Mean	SD	Mean	SD	Mean	SD	Groups in comparison	Test[a]	p-value
(a) Post own idea	4.350	1.900	3.469	1.857	2.943	1.695	All 3 groups	Kruskal-Wallis	0.000
							No vs. Low	Mann-Whitney	0.000
							No vs. High	Mann-Whitney	0.000
							Low vs. High	Mann-Whitney	0.028
(b) Give feedback	4.453	1.711	4.117	1.808	4	1.799	All 3 groups	Kruskal-Wallis	0.110
							No vs. Low	Mann-Whitney	0.160
							No vs. High	Mann-Whitney	0.040
							Low vs. High	Mann-Whitney	0.563
(c) Absorb ideas	4.898	1.720	5.398	1.549	4.729	1.888	All 3 groups	Kruskal-Wallis	0.008
							No vs. Low	Mann-Whitney	0.012
							No vs. High	Mann-Whitney	0.568
							Low vs. High	Mann-Whitney	0.004
(d) Absorb feedback	5.555	1.440	5.586	1.477	5.429	1.384	All 3 groups	Kruskal-Wallis	0.337
							No vs. Low	Mann-Whitney	0.745
							No vs. High	Mann-Whitney	0.273
							Low vs. High	Mann-Whitney	0.164
Observations	137		128		140				

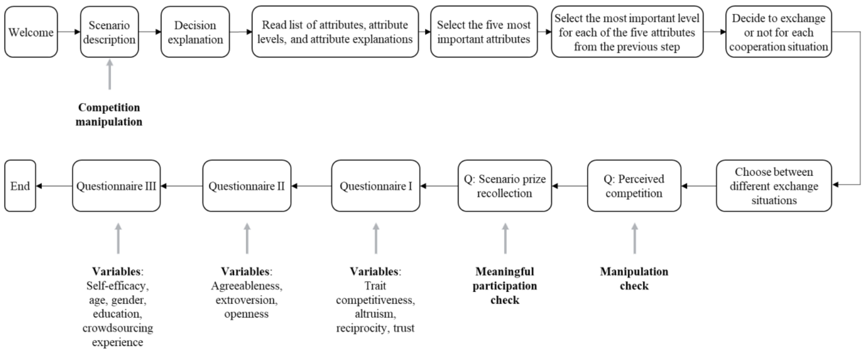
Notes. The table contains the means and standard deviation of each sharing (i.e., (a) post own idea and (b) give feedback) or absorbing (i.e., (c) absorb ideas and (d) absorb feedback) decision variables over each competition group.
[a]All variables are not normally distributed, hence, we use we use non-parametric Kruskal-Wallis equality-of-populations rank tests for three group comparisons and Mann-Whitney-U tests for two group comparisons.

Appendix 17: Study 2: List of attribute categories, attributes, attribute levels, and attribute explanation

Category	Attribute	Attribute levels	Additional attribute explanation
(a) Attributes of the focal participant	My main motivation to participate in the challenge	• Fun/Learning • My interest in the topic of the idea generation challenge • Winning a prize • Gaining career benefits from submitting one of the best ideas	No additional explanation
	My personal knowledge and skills that enable me to win	• I have all relevant knowledge and skills • I have little relevant knowledge or skills	The knowledge and skills I have that influence the likelihood for me to develop one of the best ideas and win this idea generation challenge.
	Type of knowledge I can share with others	• My entire initial idea • Selected parts of my initial idea • Up- / downvotes on other's ideas • Specific comments on others' ideas	No additional explanation
	Effort it takes me to share my idea and knowledge with others	• Considerable effort • Moderate effort • Little effort	The effort (time and other resources) it takes me to share my idea and knowledge (i.e., comments) with other participants.
	Effort it takes me to incorporate ideas and knowledge from others	• Considerable effort • Moderate effort • Little effort	The effort (time and other resources) it takes me to incorporate ideas and knowledge (i.e., comments) from other participants.
	My performance in previous challenges	• Top-performing • Average-performing • Low-performing	How I performed in previous idea generation challenges with respect to developing high quality ideas.
(b) Attributes of "other participants"	Helpfulness of ideas and knowledge shared by others	• Much helpful knowledge • Some helpful knowledge • Little helpful knowledge	The amount of helpful ideas and knowledge (i.e., comments) previously provided to me or to others by participants in this idea generation challenge.
	Previous performance of other participants	• Top-performing participants • Average-performing participants • Low-performing participants	How well the participants in this challenge did in previous idea generation challenges (as indicated on the platform leaderboard). The platform leaderboard displays how well other participants have performed in previous challenges with respect to developing high quality ideas.
	Similarity of ideas and knowledge shared with me compared to my own	• Similar • Different but complementary • Different but not complementary	The similarity of the ideas and knowledge (i.e., comments) shared with me in this idea generation challenge compared to my own idea and knowledge. For example, are the other ideas and comments similar to mine or different but complementary.
(c) Attributes of the contest	Amount of time remaining until the final idea submission deadline	• A few hours • A few days	No additional explanation

		• A few weeks	
	Main purpose of this challenge	• Serves primarily a social purpose • Serves primarily a commercial purpose	Whether the outcome of this idea generation challenge is used for a social or a commercial purpose.
	Existence of rules preventing pure copying	• No such rules exist • Such rules exist	The existence of rules that prevent participants from simply copying and submitting ideas and knowledge (i.e., comments) shared by other participants as their own. These rules are enforced by the platform.
	Complexity of the problem	• Low • Medium • High	The complexity of the problem that this idea generation challenge is trying to solve.
	Possibility to co-submit the idea with other participants	• I can co-submit with others • I cannot co-submit with others	The possibility to team up with some other participants as the challenge progresses and jointly submit one idea.
	Existence of rewards for sharing ideas and knowledge with others	• No such rewards exist • Such rewards exist	The existence of rewards for participants who perform particularly well in sharing their idea and knowledge (i.e., comments) with other participants.

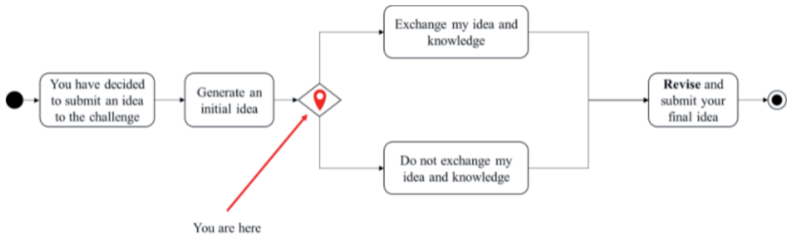
Appendix 18: Study 2: ACBC overview



Appendix 19: Study 2: Explaining the decision that can be influenced by certain factors (screenshot of page 3 in the ACBC)

The factors that influence your decision in this scenario

Please try to imagine vividly that you find yourself in the previously described situation. Particularly recall that you have the option to exchange your idea and knowledge with other participants before revising and submitting your final idea (see figure below). Remember that you have already decided to participate in the idea generation challenge and generated an initial idea.



Your task is now to think about the factors that would influence your decision to exchange your idea and knowledge with other participants (or not) in this scenario. On the next page, you will see a list of factors that may or may not influence your decision.

Once you have read the instructions and viewed the picture on this page, please click "Next". (The button to go to the next page will appear after 30 seconds.)

0% 100%

Appendix 20: Study 2: Reading the list of potentially influencing factors (partial screenshot of page 4 in the ACBC)

List of factors that might influence your decision to exchange your idea and knowledge in the scenario

Below you can see a **list of factors** (in alphabetical order) **that may or may not influence someone's decision to exchange their idea and knowledge in the previously described** scenario.

Click here to read the scenario and view the platform picture again

The factor levels describe the different ways a factor could be present in the scenario.

Please review this list and make sure that you **understand what each factor means** by also reading the description. [Please note that you do not need to memorize the factors; simply understand what each factor means. On the next page, you will then need to select those factors that would influence your decision to exchange your idea and knowledge with other participants (or not) in this scenario.]

The button to go to the next page will appear after 2 minutes.

Factor	Factor levels	Additional explanation
Amount of time remaining until the final idea submission deadline.	• A few hours • A few days • A few weeks	*No additional explanation*
Complexity of the problem	• Low • Medium • High	The complexity of the problem that this idea generation challenge is trying to solve.
Effort it takes me to incorporate ideas and knowledge from others	• Considerable effort • Moderate effort • Little effort	The effort (time and other resources) it takes me to incorporate ideas and knowledge (i.e., comments) from other participants.
Effort it takes		The effort (time and other

[*Note*: the table with the factor, factor levels, and additional explanations continued for participants. Due to size constraints of the page in this paper and readability issues with a zoomed-out screenshot, we inserted only a partial screenshot of the experimental study page.]

Appendix 21: Study 2: Selecting the 5 most important factors to exchange your idea and knowledge (partial screenshot of page 5 in the ACBC)

Please **select 5 factors** you consider to be most important in your **decision to exchange your idea and knowledge** in the previously described scenario (or not).

Some of these factors represent features of the innovation platform that were not explicitly mentioned in the scenario text, but are displayed on the picture of the challenge platform.

Click here to read the scenario and view the platform picture again

Click here to read the list of factors and their explanations again

As a reminder, you know about the **number of participants** and the **prizes in the scenario**. Below are **additional factors** that could influence your **decision to exchange your idea and knowledge** with other participants or not.

- [ ] Effort it takes me to incorporate ideas and knowledge from others
- [ ] Amount of time remaining until the final idea submission deadline
- [ ] Main purpose of this challenge
- [ ] Type of knowledge I can share with others
- [ ] My main motivation to participate in the challenge
- [ ] Possibility to co-submit the idea with other participants
- [ ] Effort it takes me to share my idea and knowledge with others
- [ ] Complexity of the problem
- [ ] My personal knowledge and skills that enable me to win
- [ ] Helpfulness of ideas and knowledge shared by others
- [ ] My performance in previous challenges
- [ ] Similarity of ideas and knowledge shared with me compared to my own
- [ ] Existence of rewards for sharing ideas and knowledge with others
- [ ] Existence of rules preventing pure copying
- [ ] Previous performance of other participants

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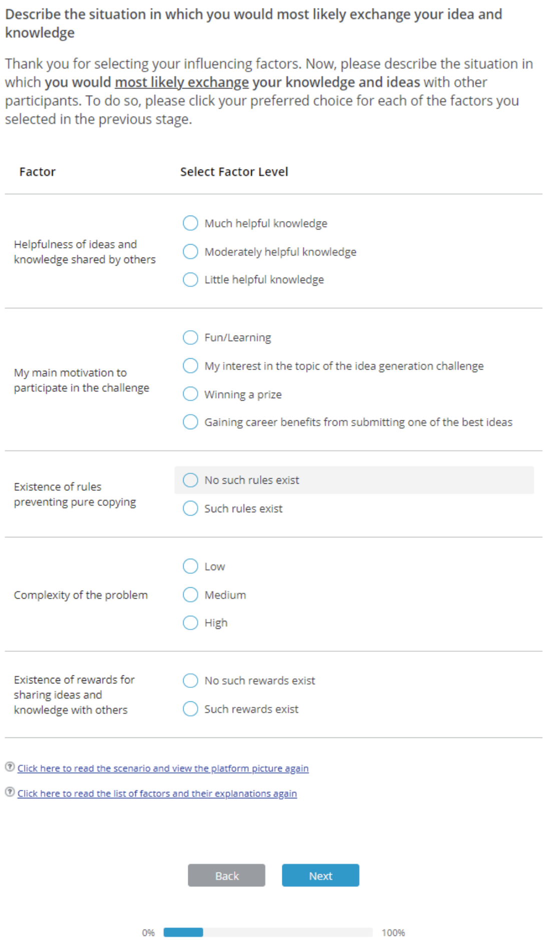
Appendix 22: Study 2: Build your own “optimal” situation in which you would exchange your idea and knowledge (partial screenshot of page 6 in the ACBC)



Describe the situation in which you would most likely exchange your idea and knowledge

Thank you for selecting your influencing factors. Now, please describe the situation in which **you would most likely exchange your knowledge and ideas** with other participants. To do so, please click your preferred choice for each of the factors you selected in the previous stage.

Factor	Select Factor Level
Helpfulness of ideas and knowledge shared by others	Much helpful knowledge Moderately helpful knowledge Little helpful knowledge
My main motivation to participate in the challenge	Fun/Learning My interest in the topic of the idea generation challenge Winning a prize Gaining career benefits from submitting one of the best ideas
Existence of rules preventing pure copying	No such rules exist Such rules exist
Complexity of the problem	Low Medium High
Existence of rewards for sharing ideas and knowledge with others	No such rewards exist Such rewards exist

Click here to read the scenario and view the platform picture again

Click here to read the list of factors and their explanations again

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Appendix 23: Study 2: Deciding to exchange your idea and knowledge or not (partial screenshot of page 7 in the ACBC)

Here are a few situations with the factors and the levels you chose before. Each column represents a situation. For each situation, please **indicate whether you would exchange your idea and knowledge with other participants** or not in the previously described scenario.

(Decision task 1 of 8) – *Please scroll down to see the choices*

	Situation 1	Situation 2	Situation 3	Situation 4
Helpfulness of ideas and knowledge shared by others	Moderately helpful knowledge	Moderately helpful knowledge	Little helpful knowledge	Much helpful knowledge
My main motivation to participate in the challenge	Fun/Learning	Gaining career benefits from submitting one of the best ideas	Fun/Learning	My interest in the topic of the idea generation challenge
Existence of rules preventing pure copying	No such rules exist	Such rules exist	Such rules exist	No such rules exist
Complexity of the problem	Medium	High	High	Low
Existence of rewards for sharing ideas and knowledge with others	Such rewards exist	Such rewards exist	No such rewards exist	Such rewards exist
	◯ Yes, I would exchange my idea and knowledge	◯ Yes, I would exchange my idea and knowledge	◯ Yes, I would exchange my idea and knowledge	◯ Yes, I would exchange my idea and knowledge
	◯ No, I would not exchange my idea and knowledge	◯ No, I would not exchange my idea and knowledge	◯ No, I would not exchange my idea and knowledge	◯ No, I would not exchange my idea and knowledge

Click here to read the scenario and view the platform picture again

Click here to read the list of factors and their explanations again

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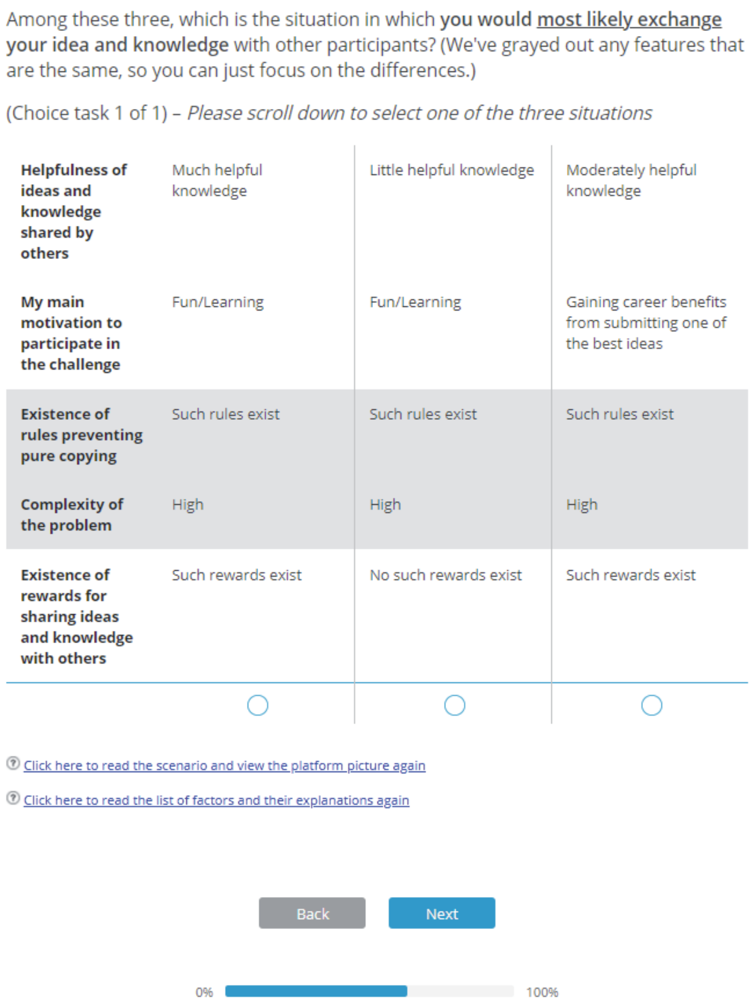
Appendix 24: Study 2: Choosing the most likely situation to exchange your idea and knowledge (partial screenshot of the ACBC)



Among these three, which is the situation in which **you would <u>most likely exchange</u> your idea and knowledge** with other participants? (We've grayed out any features that are the same, so you can just focus on the differences.)

(Choice task 1 of 1) – *Please scroll down to select one of the three situations*

Helpfulness of ideas and knowledge shared by others	Much helpful knowledge	Little helpful knowledge	Moderately helpful knowledge
My main motivation to participate in the challenge	Fun/Learning	Fun/Learning	Gaining career benefits from submitting one of the best ideas
Existence of rules preventing pure copying	Such rules exist	Such rules exist	Such rules exist
Complexity of the problem	High	High	High
Existence of rewards for sharing ideas and knowledge with others	Such rewards exist	No such rewards exist	Such rewards exist

Click here to read the scenario and view the platform picture again

Click here to read the list of factors and their explanations again

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Appendix 25: Study 2: Pairwise correlation table

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Agreeableness	1.00										
(2) Altruism	0.47^{***}	1.00									
(3) Extroversion	0.15^{***}	0.16^{***}	1.00								
(4) Openness	0.16^{***}	0.16^{***}	0.28^{***}	1.00							
(5) Perceived competition	0.05	0.10^{*}	0.03	-0.01	1.00						
(6) Rec.: Creditor ideology	0.20^{***}	0.28^{***}	0.12^{**}	0.06	0.15^{***}	1.00					
(7) Rec.: Reciprocation wariness	-0.38^{***}	-0.44^{***}	-0.15^{***}	-0.14^{***}	-0.02	-0.11^{*}	1.00				
(8) Trait competitiveness	0.05	0.03	0.25^{***}	0.14^{**}	0.19^{***}	0.23^{***}	-0.00	1.00			
(9) Trust	0.53^{***}	0.31^{***}	0.25^{***}	0.13^{**}	0.08^{+}	0.17^{***}	-0.24^{***}	0.07	1.00		
(10) Self-efficacy	0.25^{***}	0.17^{***}	0.43^{***}	0.26^{***}	0.11^{*}	0.06	-0.13^{**}	0.39^{***}	0.27^{***}	1.00	
(11) Age (log.)	0.12^{**}	-0.02	-0.00	0.11^{**}	0.00	-0.03	-0.07^{+}	-0.06	0.05	0.09^{*}	1.00
(12) Crowdsourcing experience	-0.03	-0.05	0.05	0.17^{***}	0.06	0.08^{+}	0.06	0.06	-0.01	0.06	0.02
(13) Education	0.12^{**}	0.06	0.08^{+}	0.03	0.02	-0.01	-0.04	0.05	0.11^{**}	0.20^{***}	0.37^{***}
(14) Gender (1 = female)	0.05	0.15^{***}	0.10^{*}	0.09^{*}	-0.01	-0.07^{+}	-0.19^{***}	-0.08^{+}	0.07	-0.01	-0.01

	(12)	(13)	(14)
(12) Crowdsourcing experience	1.00		
(13) Education	0.06	1.00	
(14) Gender (1 = female)	-0.01	0.06	1.00

Notes. Observations: 562. $^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Appendix 26: Study 2: The 5 most frequently selected attributes to be included in an individual's 5 most important attributes across competition groups

Attribute rank	**No competition**	**Low competition**	**High competition**
1	Copying rules (53%)	Copying rules (67%)	Copying rules (68%)
2	Sharing rewards (52%)	Sharing rewards (59%)	Sharing rewards (53%)
3	Helpfulness of shared knowledge (45%)	Helpfulness of shared knowledge (52%)	Helpfulness of shared knowledge (45%)
4	Complexity of the problem (40%)	My personal knowledge and skills (36%)	Complexity of the problem (42%)
5	Main participation motivation (44%)	Main participation motivation Complexity of the problem (both 35%)	Main participation motivation (37%)

Notes. The percentages below each attribute name display the percentage of participants (by each competition group) that selected the attribute into their list of the 5 most important attributes. This does not necessarily imply that the attribute was an individual's most important attribute.

Appendix 27: Study 2: Contrasting the Study 2 results with the results of the prediction study with respect to the five most frequently selected attributes to be included in an individual's five most important attributes across competition groups in stage 1 of the ACBC task

Attribute rank	**No-competition condition**		**Lowly-competitive condition**		**Highly-competitive competition**	
	ACBC results[a]	**Prediction study**[b]	**ACBC results**	**Prediction study**	**ACBC results**	**Prediction study**
1	Copying rules (53%)	Complexity of the problem (52%)	Copying rules (67%)	Sharing rewards (64%)	Copying rules (68%)	Sharing rewards (66%)
2	Sharing rewards (52%)	Sharing rewards (48%)	Sharing rewards (59%)	Helpfulness of shared knowledge (48%)	Sharing rewards (53%)	My personal knowledge and skills (50%)
3	Helpfulness of shared knowledge (45%)	Effort to share (42%)	Helpfulness of shared knowledge (52%)	Complexity of the problem (47%)	Helpfulness of shared knowledge (45%)	Helpfulness of shared knowledge (46%)
4	Complexity of the problem (40%)	Helpfulness of shared knowledge (42%)	My personal knowledge and skills (36%)	My personal knowledge and skills (47%)	Complexity of the problem (42%)	Effort to share (42%)
5	Main participation motivation (44%)	Effort to incorporate (40%)	Main participation motivation Complexity of the problem (both 35%)	Effort to share (43%)	Main participation motivation (37%)	Complexity of the problem (38%)

Notes.

[a] The percentages below each attribute name display the percentage of participants (by each competition group) that selected the attribute into their list of the five most important attributes. This does not necessarily imply that the attribute was an individual's most important attribute.

[b] The attributes displayed in the prediction study column show the attribute that the prediction study participants estimated to be among the 5 most important attributes. The percentages below each attribute name display the percentage of participants (by each competition group) that estimated the attribute to be among the five most important attributes. As an example from the no competition group, 53% of our Study 2 participants actually selected the attribute "copying rules" as one of their five most important attributes. However, 52% of our prediction study participants estimated that the attribute "complexity of the problem" would be among the 5 most important attributes. Hence, the most frequently selected attribute differs from the most frequently estimated attribute.

Chapter 3 – Crowdsourcing and Innovation Performance:

The Moderating Role of Digital Capabilities

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3.1. Abstract

Crowdsourcing is viewed as a solution to distant search by attracting a large number of diverse and distant ideas. While previous literature has focused mainly on the generation of these crowdsourcing outcomes, we know little about firms' translation of these outcomes into innovation performance. Moreover, evidence suggests that crowdsourcing is of low importance to firms and frequently fails. Hence, we need a better understanding of the boundary conditions that specify under which conditions the ideas generated through crowdsourcing translate into firms' innovation performance. I argue that the benefits of crowdsourcing also form its drawbacks, as evaluating and exploiting such a vast number of ideas posit significant information-processing challenges to the firm. Drawing on the literature on information processing and digitalization in organizations, I theorize that digital capabilities can be such a boundary condition that enables the translation of crowdsourced outcomes into firms' innovation performance. Using a sample of 1,657 German firms, I show that crowdsourcing relates to higher innovation performance, but the extent depends strongly on firms' digital capabilities. These findings advance our understanding of the relationship between crowdsourcing as an innovation method and innovation performance, as well as the role and benefits of digital capabilities in organizations to overcome information-processing challenges in distant search.

Keywords: crowdsourcing, search, external knowledge sources, digital capabilities, information processing

3.2. Introduction

In the last decades, firms have increasingly opened up their innovation activities from predominantly being conducted in-house to including knowledge from external sources (Chesbrough 2003, Katila and Ahuja 2002, Laursen and Salter 2006). One particularly interesting approach to sourcing external knowledge is crowdsourcing (Bayus 2013, Boudreau and Lakhani 2013, Poetz and Schreier 2012). It is understood as the act of broadcasting an innovation-related task to a large and primarily unknown crowd of diverse individuals, who, in exchange for a prize, are attracted to submit their ideas (Howe 2006, 2008, Jeppesen and Lakhani 2010). While prior literature has mainly investigated the idea generation stage of crowdsourcing efforts (e.g., Poetz and Schreier 2012, Terwiesch and Xu 2008), we know little about the implications of using crowdsourcing as an innovation method for a firm's innovation performance. This is important, as the generation of ideas by individuals outside the organizational boundary is not equivalent to the organization successfully recognizing, assimilating, and exploiting the best ideas.

Prior literature has provided some evidence that crowdsourced ideas can outperform expert-generated ideas in terms of sales revenues and gross margins (Nishikawa et al. 2013). However, there is plenty of evidence that crowdsourcing remains of low importance to firms (Chesbrough and Brunswicker 2014), can overwhelm firms (Blohm et al. 2013), and regularly fails (Acar 2019, Dahlander and Piezunka 2014, 2020). Hence, it appears that the boundary conditions for translating outcomes of crowdsourcing processes into firms' innovation performance are not understood well enough.

From a theoretical perspective, the promises of crowdsourcing may simultaneously constitute its pitfalls. On the one hand, crowdsourcing enables distant search by attracting a large number of diverse and distant ideas (Afuah and Tucci 2012). On the other hand, distant search requires firms to have sufficient information-processing capabilities. Firms that do not possess the capabilities to evaluate, assimilate, and exploit a large number of diverse and distant ideas are unlikely to benefit from crowdsourcing outcomes. The difficulty of this can be seen in the example of BP: After the Deepwater Horizon accident, BP received 100,000 ideas to separate and collect the spilled oil from the ocean. The vast number of ideas made it near impossible to evaluate all, and the crowdsourcing effort did, in fact, not result in any successful outcome (Dahlander and Piezunka 2020, Piezunka and Dahlander 2015). Apparently, crowdsourcing can leave organizations with an overwhelming number of ideas and make it difficult to separate the better from the worse ideas (Acar 2019, Blohm et al. 2013). Hence, this paper asks how the use of crowdsourcing as an innovation method impacts firms' innovation performance and which conditions positively influence this relationship.

First, I draw on literature discussing external search (Katila and Ahuja 2002, Laursen and Salter 2006) and crowdsourcing (Afuah and Tucci 2012, Poetz and Schreier 2012) to examine how the ideas generated from the crowd can translate to firms' innovation performance. Second, I add information-processing literature (Simon 1978, Tushman and Nadler 1978) and argue that crowdsourcing, as a mechanism for distant search, faces heightened information-processing demands. This is due to crowdsourcing involving a large number of ideas that need to be evaluated and knowledge that is of great distance to firms knowledge bases (Acar 2019, Blohm et al. 2013). I argue that this is a reason for the innovation performance differences observed in previous literature. Based on literature investigating organizational capabilities (Grant 1996a) and the digitalization of organizations (Nambisan et al. 2019, Ritter and Pedersen 2019, Wu et al. 2020), I conceptualize digital capabilities as the skills and routines a firm possesses for using digital data and technologies in their value creation efforts. I then theorize that digital capabilities allow firms to capture value from distant search by overcoming its inherent information-processing challenges. They do so by easing the evaluation of the crowdsourced ideas, relating them to prior organizational knowledge, and enhancing the discovery and recombination of knowledge.

My paper tests two theoretical predictions on a sample of 1,657 German firms from the Mannheim Innovation Panel Data in 2019. The data contains information on the firms' use of crowdsourcing, the extent of digital capabilities, and innovation performance. First, I find a positive relationship between the use of crowdsourcing as an innovation method and innovation performance in most empirical models, yet not in all, indicating that the relationship is not unambiguous. Hence, in the second step, I add digital capabilities as a moderating boundary condition to the estimations and provide evidence for a positive interaction effect between crowdsourcing and digital capabilities on innovation performance. This highlights the importance of the boundary condition, i.e., digital capabilities, for crowdsourcing.

This paper makes three contributions to the existing literature. First, I conceptualize digital capabilities as an enhancer of firms' ability to benefit from distant search activities by reducing information-processing limitations and improving absorptive capacity. In doing so, I extend the literature on external search (Chesbrough 2003, Laursen and Salter 2006) and, in particular, distant search (Katila and Ahuja 2002, March 1991) by theorizing on boundary conditions for the translation of external knowledge inputs into innovation performance. Second, I provide evidence on the relationship between crowdsourcing and firms' innovation performance across a variety of firms and industries. While the results indicate that this relationship is positive, not all empirical models are unanimous in this interpretation. Nevertheless, these insights advance the literature on crowdsourcing (Bayus 2013, Nishikawa et al. 2013, Poetz and Schreier 2012) by offering systematic evidence on the implications of translating external search outcomes into innovation performance. Lastly, I present evidence on the role of digital capabilities in helping firms overcome information-processing challenges related to distant search activities (Simon 1978, Tushman and Nadler 1978, Wu et al. 2020). This highlights the importance of boundary conditions for using external search methods and, thereby, advances existing literature on external search (Chesbrough 2003, Katila and Ahuja 2002) and crowdsourcing (Afuah and Tucci 2012, Piezunka and Dahlander 2015).

3.3. A review of external search and digitalization

3.3.1. External search and crowdsourcing

In the quest for a competitive advantage, firms search for uniquely available knowledge (Grant 1996b, Liebeskind 1996, Subramaniam and Venkatraman 2001). This paper focuses on a firm's external search for such knowledge, i.e., a firm's opening up of their innovation process to external knowledge and combination of it with their internal knowledge (Cassiman and Veugelers 2002, Chesbrough 2003, Dahlander and Gann 2010, Katila and Ahuja 2002, Laursen and Salter 2006). Reaching beyond the boundaries of the firm (Rosenkopf and Nerkar 2001) can lead to an increased return on investment for R&D expenditures (Nadiri 1993), enhance innovation performance (Grimpe and Sofka 2009, Laursen and Salter 2006, Leiponen and Helfat 2010), and improve subsequent technological evolution (Rosenkopf and Nerkar 2001).

External search can be further distinguished into two modes. First, searching for knowledge inside the decision-maker's neighborhood represents "local" search (Cyert and March 1963, Katila and Ahuja 2002, Winter et al. 2007) and is often referred to as exploitation (March 1991). Second, "distant" search or exploration (March 1991) occurs outside of the neighborhood of a decision-maker

(Cyert and March 1963, Gruber et al. 2013, Nelson and Winter 1982). In the former, the decision-maker is deemed to have sufficient information and resources for evaluating and decision-making, while this is most often not the case in the latter (Afuah and Tucci 2012).

A particularly intriguing external search method is crowdsourcing. In engaging with crowdsourcing, firms broadcast an innovation-related task to a large and oftentimes unknown external crowd with the hope that someone with an idea self-selects into revealing it to the firm (Afuah and Tucci 2012, Howe 2006, Jeppesen and Lakhani 2010, Riedl and Woolley 2017). First examples of crowdsourcing date back to 1418, when a goldsmith won the crowdsourcing contest for the design of the Cathedral of Santa Maria del Fiore dome in Florence, Italy (King 2008). Other examples include Napoleon's Food Preservation Prize, the British Longitude Prize in 1714 (Andrewes 1996), and NASA's recent solar flare prediction problem that a retired radio frequency engineer solved (Knowledge at Wharton 2013). As exemplified in these instances, crowdsourcing can enable firms to search distantly (Afuah and Tucci 2012), i.e., search for knowledge outside of the firm's boundaries or neighborhood. It does so by attracting a large number (Blohm et al. 2013, Boudreau et al. 2011) of diverse as well as technically and socially marginal participants (Boudreau and Lakhani 2013, Jeppesen and Lakhani 2010), who can provide a different set of ideas than internal firm experts can (Nishikawa et al. 2013, Poetz and Schreier 2012).

3.3.2. Boundary conditions for translating external search results into innovation performance

An important enabler for translating the results of external search processes into innovation performance is a firm’s ability to recognize, assimilate, and exploit external knowledge. This is known as a firm’s absorptive capacity (Cohen and Levinthal 1990). These absorptive capabilities allow a firm to search and recognize relevant external knowledge sources and translate that knowledge so that it can be assimilated with the firm's existing knowledge stock (Grimpe and Sofka 2009, Todorova and Durisin 2007). Possessing absorptive capacities can allow a firm to learn about a specific field in terms of market and technology trends (Grimpe and Sofka 2009), provide a more diverse set of problem-solving knowledge (March 1991), and forecast prospective developments (Cohen and Levinthal 1994). Empirically, the extent of a firm’s internal research and development has often been used as a proxy for absorptive capacity and provided further support for this theory (e.g., Cassiman and Veugelers 2006, Cohen and Levinthal 1990).

Other research on user innovation has suggested that integrating knowledge from customers or users requires new organizational practices to influence innovation: for example, increasing vertical and lateral communication to distribute the knowledge through the organization, putting knowledge sharing inducing rewards in place, and delegating decision-rights through broader job descriptions or projects (Foss et al. 2011). Similarly, other work proposes that organizational capabilities, such as creating dedicated external search roles and processes for the expression and systematizing of knowledge, assist in turning external knowledge into innovation performance (Pollok et al. 2019).

Further, the literature finds an inverted curvilinear relationship between the number of external knowledge sources and innovation performance (Laursen and Salter 2006). This indicates that increasing the number of external knowledge sources too far may reduce the value a firm is able to capture from them. Some of these external knowledge sources may also complement the knowledge of each other, for example, collaborations and markets for technology, depending on the level of technology in the firm's operating industry (Grimpe and Sofka 2016).

In sum, previous literature provides us with an understanding of organizational capabilities that enable firms to translate external search results into innovation performance and boundary conditions for selecting and combining external knowledge sources. However, previous literature offers little guidance explicitly tailored to distant search activities, particularly crowdsourcing, and the role digital capabilities can play in this translation and external search more generally.

3.3.3. Digitalization and innovation

Digitalization is the use of digital data and technologies in organizations (Nambisan et al. 2017, Ritter and Pedersen 2019, von Krogh 2018) and can impact the innovation processes of firms in two main ways (Nambisan et al. 2017, Nambisan et al. 2019, Yoo et al. 2010, Yoo et al. 2012). First, digitalization can promote information collection for innovation processes in new ways and vast amounts. For example, digital technologies allow for the collection of large amounts of data (Mooney and Pejaver 2018) either by the firm itself or through acquisitions on data markets (Dahlander et al.

2021, Alexy et al. 2013). This can help them to recognize the most profitable innovations (Clemons et al. 1995) and facilitate the generation of new knowledge (Joshi et al. 2010, Majchrzak and Malhotra 2016). Digital technologies also enable the involvement of consumers in the innovation process, e.g., through the application of online experiments that quickly generate data on the expected success of innovations in an affordable manner (Kohavi and Thomke 2017) or the evaluation of new product ideas (Hofstetter et al. 2018). This means that digital technologies enable firms to access a larger volume and variety of information in the innovation process.

Second, digitalization can enable new ways of information analysis, processing, and generation. Data analytics have received significant attention as they allow a firm "to process, analyze, and transform data to detect patterns, find useful insights, and support decision making" (Wu et al. 2020, p. 2025). They expand the space where firms search, increase information processing speed, and enhance the likelihood of successfully combining diverse knowledge sets (Wu et al. 2020). For example, BASF uses artificial intelligence to assess and synthesize scientific literature with other sources in the quest to create novel materials or run simulations and compute complex models (Mullin 2017). Similarly, Watson, the cognitive computing technology by IBM, identified 15 drug candidates in only one month – a process that took ten researchers 14 months for a similar number (Chen et al. 2016). Recent empirical evidence shows that the use of data analytics can, indeed, lead to improved firm innovation (Wu et al. 2020), and other firm-level evidence shows a positive correlation between AI and industrial innovation success (Rammer et al. 2022).

3.4. Development of hypotheses

3.4.1. Crowdsourcing and innovation performance

The need for and benefits of firms engaging in external knowledge search (Cassiman and Veugelers 2006, Chesbrough 2003) and, specifically, in distant search are well documented (Katila and Ahuja 2002, March 1991). Prior literature has proposed that crowdsourcing is a search mechanism that can ease this distant search process by encouraging problem solvers to self-select into submitting their ideas to the firm and, thereby, turn distant into local search (Afuah and Tucci 2012). Research on the quality of ideas from such crowdsourcing initiatives shows that crowdsourced ideas can outperform the ideas of firm-internal experts on idea quality dimensions, such as novelty and customer benefit

(Poetz and Schreier 2012). A similar study on the Japanese consumer goods brand Muji suggests that crowdsourced ideas generate higher sales revenues and gross margins than those of experts (Nishikawa et al. 2013). Lastly, integrating external knowledge generated through crowdsourcing initiatives is associated with higher innovation project success (Pollok et al. 2019). Hence, I propose:

Hypothesis 1: There is a positive relationship between crowdsourcing and firms' innovation performance.

3.4.2. Digital capabilities: translating crowdsourcing outcomes into innovation performance by decreasing information processing limitations

Capabilities constitute a bundle of qualifications and skills that are required to accomplish a goal (Day 1994, Drucker 1985, Ritter and Pedersen 2019). In that sense, organizational capabilities are “a firm’s ability to perform repeatedly a productive task which relates either directly or indirectly to a firm’s capacity for creating value through effecting the transformation of inputs into outputs” (Grant 1996a, p. 377). Such capabilities can be of an integrative nature that allow firms to access and incorporate external knowledge (Demsetz 1991, March and Simon 1958) or of a combinative nature that enable firms to explore and recombine knowledge with the goal of creating innovations (Kogut and Zander 1992). Previous literature has conceptualized capabilities relating to digitalization as a firm’s ability to create value from three dimensions: data, permission, and analytics (Gupta and George 2016, Lenka et al. 2017, Ritter and Pedersen 2019). Digital capabilities allow firms to access and retrieve large amounts of diverse data and are novel means of accessing and processing data (Yoo et al. 2012, Wu et al. 2020). In other words, digital capabilities represent a firm’s skills and routines relating to the use of digital data and technologies in creating value. I suggest that these digital capabilities can assist firms with information-processing limitations.

A central tenet in the information-processing theory of organizations is that individuals are constrained in their ability to collect, manage, and transfer information (Galbraith 1977, Simon 1978, Tushman and Nadler 1978). Prior literature suggests this is particularly strong in distant search mechanisms as they require different routines and capabilities compared to local search mechanisms (Cohen and Levinthal 1990, Kogut and Zander 1996, Nelson and Winter 1982). Reasons therefore are manifold. The number of potential ideas and their alternatives that need to be considered are usually higher in distant search, thus, leaving the decision-maker with less information and resources to reduce these and extrapolate the best idea (King 2007). This issue is further aggravated by organizations facing attention deficit problems, in the sense that attention is a scarce resource in decision-making processes (Ocasio 1997, Simon 1947). Particularly when engaging in crowdsourcing as a distant search mechanism, decision-makers are cognitively limited because "the information and resources needed to evaluate and make a decision" are only scarcely available (Afuah and Tucci 2012, p. 357). Drawing on the absorptive capacity literature (Cohen and Levinthal 1990), I argue that information-processing limitations occur in all three aspects of absorptive capacity, i.e., recognizing, assimilating, and exploiting the knowledge that is created through crowdsourcing, and that digital capabilities can support firms in alleviating these limitation problems.

First, firms face information-processing limitations when recognizing, i.e., in this context evaluating the multitude of ideas generated through crowdsourcing. Remembering the BP Deepwater Horizon evaluation, scholars have highlighted the sheer impossibility of evaluating all ideas generated by the crowd (Dahlander and Piezunka 2020, Piezunka and Dahlander 2015) and separating the better from the worse ideas (Acar 2019, Blohm et al. 2013). Digital capabilities can assist in this evaluation. For example, data analytics and artificial intelligence can help firms with pre-selecting ideas for a later in-person evaluation by the firm (Dahlander et al. 2021). They can enhance the search for prior related knowledge and improve discovery (Agrawal et al. 2019, Bianchini et al. 2020). Digital capabilities can enable firms to utilize vast troves of data (Schwab 2016, Sturgeon 2019) and assist with decision-making processes (Brynjolfsson and McElheran 2016) by easing a firm's information processing and even automating decision making (von Krogh 2018, Wu et al. 2020). In fact, LEGO already employs machine learning to identify promising ideas in their online community (Christensen et al. 2017, Dahlander et al. 2021). Further examples from market research show that AI is able to identify customer segments or market trends in an improved and quicker way (Brynjolfsson and McAfee 2014, Raisch and Krakowski 2021).

Second, once the ideas from the crowd have been evaluated and the best selected, accepting and assimilating the diverse and distant knowledge can often be a struggle for firms (Haas et al. 2015, Piezunka and Dahlander 2015). For instance, distant knowledge proposals are oftentimes disregarded in scientific committees (Boudreau et al. 2016), and knowledge from business units is ignored if the ties to the focal business unit are weak (Reitzig and Sorenson 2013) or the novelty is too high

(Criscuolo et al. 2017). Yet, crowdsourcing provides firms access to such distant knowledge, i.e., knowledge substantially different from the firm's current knowledge base (Afuah and Tucci 2012, Piezunka and Dahlander 2015). Conversely, this implies that these distant ideas might be overlooked or even avoided (Haas et al. 2015) and create resistance in the decision-makers to engage with them in the first place (see Katz and Allen 1982 for a discussion of the not-invented-here syndrome). This means that firms need different mindsets to work with such external sources (Dahlander et al. 2021).

Possessing digital capabilities can entail such a mindset. Research on the interaction of technology, mindsets, and innovation highlights that experiencing the effects of technology can act as further inspiration (i.e., a mindset change) to pursue more radical innovation activities (Ringberg et al. 2019), which are associated with more explorative distant search (Katila and Ahuja 2002, March 1991). With increasing levels of digital capabilities, firms are more prone to accumulate experience on the benefits of opening up to other actors and their diverse and distant knowledge (cf. Nambisan et al. 2019). Hence, this previous engagement has changed their mindset to be more open to accepting and actively assimilating knowledge into the organization. Work by Burcharth and Fosfuri (2015) supports this as they find that the not-invented-here syndrome, i.e., the resistance of firms to engage with distant external knowledge (Katz and Allen 1982), is reduced in high-tech companies. This indicates that firms with higher digital capabilities may be less impacted by not-invented-here resistance in their crowdsourcing activities.

Third, processing and exploiting diverse and distant knowledge for commercial ends is another challenge for firms. To learn from others' knowledge, firms are required to possess a similar knowledge base to which they can relate this new knowledge (Lane and Lubatkin 1998). Digital capabilities enable a wider collection and organization of large amounts of data, i.e., they allow firms access to a broader base of knowledge to which external knowledge can be related. Learning from this distant search then typically requires trial and error search (Henderson and Clark 1990) and is time-consuming (Haas et al. 2015), while the transformation of distant knowledge into an actual innovation requires high investments (Kotha et al. 2013, Thursby and Thursby 2002). Digital capabilities can assist with the translation of this diverse and distant knowledge by uncovering novel patterns and knowledge combinations with the existing knowledge stock, as the previous examples from BASF and IBM's Watson highlight. These capabilities enhance firms' search for new analogical ideas as well as their translation (Enkel and Gassmann 2010) and complementarities (Cheng and

Huizingh 2014). Consequently, digital capabilities ease and enhance the information-processing needs of firms and constitute a new combinatorial power that amplifies a firm's ability to exploit the external knowledge collected in crowdsourcing. In that sense, digital capabilities are especially valuable for innovation processes that require high information processing and distant search as they increase a firm’s absorptive capacity for diverse and distant knowledge. I predict:

> *Hypothesis 2: There is a positive relationship between crowdsourcing and firms' innovation performance, and this relationship is positively moderated by firms' digital capabilities.*

3.5. Data and methods

3.5.1. Data

The empirical part of this study is based on cross-sectional data from the 'Mannheim Innovation Panel' (MIP). The MIP is a representative survey on the innovation activities of German firms and was conducted in 2019, collecting data on firms' innovation activities over a three-year period from 2016 to 2018. The German Federal Ministry of Education and Research commissions the survey annually to the Center for European Economic Research (ZEW), which conducts it. The MIP is the German version of the Community Innovation Survey (CIS) and follows its standards regarding methodology and questionnaire.

The CIS surveys rely on self-reported answers by firms[28]. This can raise quality issues regarding the administration, non-response, and response accuracy (see Criscuolo et al. (2005) for a discussion). Nevertheless, several actions are taken to address these issues. First, the survey is extensively pre-tested and piloted across multiple countries, industries, and firms to ensure interpretability, reliability, and validity (Laursen and Salter 2006). Second, detailed definitions and examples are added to the questionnaire to enhance the response accuracy. Third, the survey is administered via mail in order to prevent shortcomings and biases in telephone interviews (Bertrand and Mullainathan 2001).

[28] The MIP sample is based on a stratified random sampling of German firms. More details on the MIP 2019 data and survey can be found in Rammer (2020).

An advantage of the CIS surveys is that they directly ask CEOs or managers of R&D or innovation management units to answer the survey. Hence, they provide direct and importance-weighted measures for data relating to a firm's innovation management (Criscuolo et al. 2005) and are the database on which many scholars rely (e.g., Cassiman and Veugelers 2006, Grimpe and Sofka 2016, Klingebiel and Adner 2015, Laursen and Salter 2006, Leiponen and Helfat 2011).

3.5.2. First stage selection

The reason to follow a two-stage approach is that the decision to use crowdsourcing as an innovation source is likely to be non-random. This might create biased estimation results if factors related to that decision influence the likelihood to use crowdsourcing (Certo et al. 2016). Therefore, I make an effort to address these endogeneity concerns with the two-stage approach: First, I predict the probability that a firm will use crowdsourcing as a source of knowledge. Subsequently, I test Hypotheses 1 and 2 regarding firms' relationship between the use of crowdsourcing as an innovation method and innovation performance as well as the interaction with digital capabilities. The following will describe the variables and model used in the first stage selection estimation.

Dependent variable. A firm's use of crowdsourcing as a source of innovation is measured as follows. The CIS survey asked respondents to indicate with a "yes" or a "no" whether "social (web-based) networks, crowdsourcing" was a source of knowledge their firm used between the years of 2016-2018. This results in the dummy variable crowdsourcing for which 0 is coded as "no" and 1 as "yes".

Instrumental variable. An appropriate instrumental variable correlates with the use of crowdsourcing but not the error term in the second stage explaining the innovation performance – in both cases, conditional on the other covariates. I choose the industry mean of the use of crowdsourcing as a variable that fulfills these requirements. Based on the CIS 2019 survey, I calculate the mean ratio of firms that use crowdsourcing on a three-digit NACE industry level. This underlies the assumption that firms in industries with more prevalent use of crowdsourcing are more likely to use crowdsourcing. Concurrently, the industry mean of the use of crowdsourcing should not influence the innovation performance of an individual firm. Firms deciding to use crowdsourcing should not be impacted by how many other firms in their industry also use crowdsourcing. Using the industry mean as an indicator of how fellow firms in the industry adopt a practice or adjust their behavior is an established measure (see, for example, Benson et al. 2020, Kaiser et al. 2018, or Kini and Williams 2012). In fact, the use of a relatively naïve measure as an instrument is appropriate as it likely captures levels of the variable but is not expected to capture variations around those levels that are endogenously determined (Hentschel and Kothari 2001).

Explanatory variables. The level of digital capabilities is captured by using items listed in the CIS survey that relate to the use of software and databases as well as artificial intelligence. The survey asked respondents about the former "Did your company perform the following software and database activities in 2016-2018?" and offered five items that could be selected and an additional "none" item, indicating that none of the five items were performed (see Table 2 for the list of items). The response to each item was coded as a "0" if not selected and a "1" if selected. Regarding the latter, respondents could answer the question "Does your company use artificial intelligence techniques?" with a "yes" and a "no". In the case of yes, respondents had to indicate which of the five techniques they were using. Each technique allowed for the selection of the technique's field of application. The response to each item was coded as a "0" if not selected and as a "1" if any of the technique's fields of application were chosen. I then create the digital capabilities index variable by summing up the number of items a firm selected, ranging from a minimum of zero items to a maximum of items selected. These items are particularly suitable as they fit well with the literature on digitalization that views digital capabilities as consisting of artificial intelligence, data, and software (cf. Ritter and Pedersen 2019, Syam and Sharma 2018).

Control variables. I include a variety of control variables that may influence the estimation results. In addition to the digital capabilities of a firm, the innovation performance of a firm may be affected by its research and development activities. I follow previous literature by including a firm's *R&D intensity*, i.e., R&D expenditures as a share of sales, as a control variable (Grimpe and Sofka 2009, Laursen and Salter 2006, 2014). A firm's innovation performance may also be influenced by its *export intensity* (export sales as a share of sales), as the potential for greater sales outside of the home country can create incentives for innovation (Leiponen and Helfat 2011).

Moreover, I include the *logarithm of the number of employees* as a control variable. Larger firms may have a larger customer base and easier access to financial and human resources, increasing the likelihood of generating an innovation and potentially increasing its sales (Leiponen and Helfat

2010). The performance of a firm's innovation may be affected by whether it is *part of a business group*. Being part of a business group might give a firm access to internal knowledge of other parts of the group, thus, presenting a diversified environment that can enhance innovation performance (Leiponen and Helfat 2011). I include the belonging to a business group as a dummy variable (0,1).

Firms that cooperate with other firms or institutions may improve their innovation search process (Knudsen and Srikanth 2014) and thus enhance innovation performance. The survey asked firms "Did your company engage in any cooperations in 2016-2018?" as part of their innovation activities. I incorporate a dummy variable (0,1) for whether firms engaged in *cooperation*. Lastly, the level of technology in a firm's *industry of operation* may influence customer demand, appropriability, and technological opportunities (Leiponen and Helfat 2011). The Eurostat (2020) high-tech and knowledge-intensive services industry indicators are commonly used to differentiate industries along their innovation patterns and technological nature (Grimpe and Sofka 2009, Hall 1994). The classification results in seven industry dummies (0/1) based on their two-digit NACE code level: low-tech, medium-low-tech, medium-high-tech, and high-technology manufacturing industries; less knowledge-intensive and knowledge-intensive services; and other industries that contain the remaining firms. The baseline industry is knowledge-intensive services due to the highest number of firms being assigned that industry.

Model. Building on work by Bascle (2008), Hamilton and Nickerson (2003), and Olsen et al. (2016), I run a probit model with robust standard errors in which the dependent variable is the use of crowdsourcing and the instrumental variable is the industry mean of crowdsourcing use. The model contains all other variables also present in the second stage, i.e., digital capabilities, the control variables are R&D intensity, export intensity, the number of employees (log.), part of a business group, cooperation, and the industry dummies. In a subsequent step, I calculate the inverse Mills ratio and include it as a control in the second stage.

3.5.3. Second stage Tobit

The following will describe the variables and model used in the second stage Tobit estimation.

Dependent variable. To measure innovation performance, I choose the logarithmic sales revenue from new-to-the-market product innovations as the dependent variable and, thereby, follow prior literature in the field (e.g., Laursen and Salter 2006, Köhler et al. 2012, Leiponen and Helfat 2010, 2011).

Explanatory variables. In the second stage, a firm's use of crowdsourcing and digital capabilities are the explanatory variables.

Control variables. The control variables are R&D intensity, export intensity, the number of employees (log.), part of a business group, cooperation, and the industry dummies. In addition, the second stage includes the inverse Mills ratio, which was calculated as a result of the first stage estimation, as a control variable.

Model. I use a Tobit model to obtain an estimation of the relationship between crowdsourcing and innovation performance (Hypothesis 1). Innovation performance, defined as the sales revenue from new-to-the-market product innovations, cannot take on values lower than 0. Hence, the dependent variable is censored with a minimum value of 0 for which the Tobit model accounts. Next to the explanatory and control variables, the model contains the inverse Mills ratio in the first stage and bases its standard errors on 1,000 bootstrapped replications (cf. Wooldridge 2015). For Hypothesis 2, I add the interaction term between crowdsourcing and digital capabilities.

3.6. Results

Table 18 provides descriptive statistics, Table 19 shows the distribution of firms across each level of the digital capabilities index, and Table 20 contains correlation coefficients for the main variables used in the first and second stages. The descriptive statistics highlight that 35% of the firms use crowdsourcing, and the average number of digital capabilities features used is about 2. The correlation coefficients show a moderate and positive relationship between crowdsourcing and digital capabilities (ρ = 0.24). Unsurprisingly, being part of a business group is highly and positively correlated with the logarithm of the number of employees (ρ = 0.49).

First stage results. Table 21 reports the results of the probit analyses. Model 1 shows a highly significant and positive association between the industry mean of the use of crowdsourcing, i.e., the instrumental variable, and the use of crowdsourcing. This suggests it to be a strong instrument. Interestingly, the coefficient of digital capabilities is positively and significantly related to the use of crowdsourcing, suggesting that firms with higher levels of digital capabilities are more prone to use crowdsourcing as an innovation method. As an additional outcome of Model 1, I can calculate the inverse Mills ratio and include it in all other models containing crowdsourcing as an independent variable (Models 3, 5, and 6).

Second stage results. Models 2 to 6 in Table 21 display the marginal effects of each variable on innovation performance, i.e., the logarithmic sales revenues from new-to-the-market product innovations.[29] The Tobit estimation in Model 2 includes only the control variables and industry dummies. All control variables expect business group are, unsurprisingly, significantly and positively related to innovation performance. Regarding Hypothesis 1, Models 3 and 4 show that the use of crowdsourcing has a positive and significant relationship with innovation performance. The average marginal effect of using crowdsourcing is associated with a 1.292 times higher sales revenues of new-to-the-market product innovations (exp(0.256) = 1.292). However, the marginal effect of crowdsourcing is insignificant in Model 6 when the interaction term with digital capabilities is added.

In Models 4 and 5, digital capabilities are strongly and significantly related to innovation performance, such that the average digital capabilities are related to a 1.185 higher value of innovation performance (exp(0.170) = 1.185). Again, this effect is insignificant in Model 6.

Lastly, I examine how digital capabilities interact with crowdsourcing on innovation performance. Model 6 shows that this interaction term is positive and significant. This means that firms benefit more from crowdsourcing with an increase in the extent of their digital capabilities. The average marginal effect highlights that this interaction is associated with a 1.131 times increase in sales revenues of new-to-the-market product innovations (exp(0.123) = 1.131). This supports Hypothesis 2 and suggests that crowdsourcing efforts benefit from digital capabilities. Further, this significant interaction also helps interpret the results for both the marginal effect of using crowdsourcing and digital capabilities. It suggests that the existence of a boundary condition, i.e., the interaction effect, is highly important.

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[29] Average marginal effects are displayed. This is due to the dependent variable being in natural logarithmic form and my interest lying in the effect of the independent variable on the underlying value of the non-log form. Hence, I calculate the exponentiated (exp) value of the marginal effect for dummy and continues independent variables in non-log form. For independent variables in natural logarithmic form, such as the number of employees (log.) the coefficient represents an elasticity. In that case, a 1% increase in the non-log value of the independent variable with a marginal effect of 0.1 indicates a 0.1% increase in the non-log value of the dependent variable (Leiponen and Helfat 2011, UCLA Academic Technology Services 2022).

I then continue to explore further specific aspects of digital capabilities and potential heterogeneity in the relationships regarding the type of industry. First, to better understand which aspects of digital capabilities drive the positive moderation, I rerun the analysis in Appendix 32 by substituting the digital capabilities index with a) an index only for the software and databases items (Model 1), b) each software and databases item (Models 2-6), c) an index only for the artificial intelligence items (Model 7), and d) each artificial intelligence item (Models 8-12). I find that both indices for software and databases as well as artificial intelligence positively moderate the relationship between crowdsourcing and innovation sales at a 10% significance level (see Models 1 and 7). Moreover, the moderation seems to be driven by the items *systematic analysis of large data* (Model 6: $p<0.1$), *AI image recognition* (Model 9: $p<0.01$), and *AI machine learning* (Model 10: $p<0.05$). Interestingly, items related to the simple purchase of software programs or data or speech recognition do not show a significant interaction. These findings support the theoretical arguments that digital capabilities can assist firms in their information-processing efforts, as items specifically related to information processing show significance, whereas rather general digital items do not.

Second, I explore whether there is heterogeneity in the results depending on the industry. For example, prior literature on external search has often only studied manufacturing firms in order to isolate effects to a specific industry (e.g., Grimpe and Sofka 2009, Laursen and Salter 2006), while others have argued that service firms can differ in their innovation activities and, thus, merit special attention (Delgado and Mills 2020). Therefore, I rerun my analysis separately for each industry type by splitting my sample into manufacturing firms (Appendix 33), service firms (Appendix 34), and other firms (Appendix 35). The results suggest that there is no significant relationship between crowdsourcing and innovation sales, as well as no significant moderation by digital capabilities in the service and other industries (see Appendix 34 and Appendix 35). However, there is a positive relationship between crowdsourcing and innovation sales (Appendix 33, Model 3: $p<0.1$), and this is positively moderated by digital capabilities (Model 6: $p<0.001$).

Consistency checks. I conduct a number of consistency check estimations to these results. First, estimating interaction effects in non-linear models may confound the moderating effect with the nonlinearity of the model (Andersson et al. 2014, Bowen 2012). Hence, I rerun the estimations from Table 21 as an OLS regression instead of a Probit and Tobit in each model. The results are displayed in Appendix 28 and are consistent with the original estimations.

Second, interacting the instrumented variable without a second instrument may not be without concern (Certo et al. 2016, Hill et al. 2021, Wolfolds and Siegel 2019). Hence, I triangulate this identification approach by eliminating the need for an interaction term with two separate estimations on a sample split by variable that crowdsourcing is interacted with, i.e., digital capabilities. More precisely, I split the sample into firms whose extent of digital capabilities equal 0 (i.e., the firm does not have digital capabilities) and those higher or equal to 1 (i.e., the firm has digital capabilities). I then estimate the relationship between crowdsourcing and innovation performance in both samples in the same manner as the models in Table 21. The results in Appendix 29 suggest that crowdsourcing does not relate to innovation performance when digital capabilities do not exist (the marginal effect in Model 2 is not significant, $p > 0.05$). However, considering the sample of firms that do have digital capabilities in Model 3, I find a significant and positive marginal effect of crowdsourcing on innovation performance. This indicates that the relationship of crowdsourcing on innovation performance is, indeed, moderated by firms' digital capabilities and, thus, consistent with the previously reported results.

Third, to check whether my findings are only the result of including an instrumental variable, I re-estimate all models without controlling for endogeneity using OLS regressions. Appendix 30 shows that the findings remain consistent.

Fourth, due to the potential selection bias of using crowdsourcing, I estimate the average treatment effect on the treated using propensity-score matching (Abadie and Imbens 2006, 2011). I match on all control variables, namely R&D intensity, export intensity, number of employees, business group, cooperation, and on the digital capabilities variable. I employ Stata's *teffects psmatch* command, and the results can be seen in Appendix 31. The significant coefficient of crowdsourcing on innovation sales (log.) supports the findings for Hypothesis 1.

3.7. Discussion

This paper set out to study when firms engage in crowdsourcing and under which conditions crowdsourcing as an innovation method improves firms' innovation performance. While prior literature on crowdsourcing has studied the outcomes of crowdsourcing efforts in terms of how to generate the highest-performing ideas (Poetz and Schreier 2012, Terwiesch and Xu 2008), little is known about the adoption of these outcomes by firms and their effect on innovation performance. In fact, there is some evidence on the potentially positive innovation performance effects not materializing (Chesbrough and Brunswicker 2014, Dahlander and Piezunka 2014, 2020). I address this gap in our understanding of the innovation performance effects of adopting crowdsourcing effort outcomes by theorizing on how the information processing challenges of crowdsourcing can be overcome. In particular, I shed light on how digital capabilities of organizations (Nambisan et al. 2019, Ritter and Pedersen 2019, Yoo et al. 2012) can assist firms in overcoming these information-processing limitations (Simon 1978, Tushman and Nadler 1978, Wu et al. 2020). This advances our understanding of boundary conditions for engaging with distant search and contributes to the literature on external and distant search (Laursen and Salter 2006, Katila and Ahuja 2002).

In the empirical part of this paper, I test two predictions with innovation-related data from 1,657 German firms. This paper fills the gap of how using crowdsourced ideas in the innovation process relates to innovation performance. Interestingly, I find that this relationship is not entirely unambiguous. The results show that the marginal effects of crowdsourcing are positively and significantly related to innovation performance in two models but insignificant in the model with the interaction term.

So, what could explain these differences from previous studies on the positive effects of crowdsourcing? I conjecture that this paper's number of firms and conceptualization of the dependent variable differ from previous literature. For example, a prominent study by Poetz and Schreier (2012) uses ideas generated for the Bamed/MAM Group. They compared the ideas generated by company-internal employees to those crowdsourced from users and then evaluated the ideas on idea novelty, customer benefit, and feasibility. This study contributed greatly to our understanding of who can generate better ideas but is limited in its ability to explain the realized performance outcome of those ideas. In line with the literature on absorptive capacity (Cohen and Levinthal 1990, Zobel 2017), the availability of ideas may not suffice to turn ideas into successful innovation but requires the recognition, assimilation, and, ultimately, exploitation of those ideas – which is much more complex and may hinder promising ideas to become successful. My paper indicates that there are differences between firms and their ability to adopt the outcomes of crowdsourcing efforts.

A subsequent study that involves one of the two previous authors addresses this issue by measuring innovation performance as "aggregate unit sales generated in the first year after market introduction. In addition, we capture profitability by measuring the products' monetary value of sales and gross margins" (Nishikawa et al. 2013, p. 163). They compare ideas generated by professional designers to crowdsourced user ideas for the company Muji. While that study enhances our understanding of the potential commercial outcomes, a generalization of the results hinges upon the assumption that every firm has the same digital capabilities to process the information received through crowdsourcing as Muji has. My results suggest that this is not necessarily the case.

A recent paper by Pollok et al. (2019) collects data from multiple firms across a variety of industries and measures how their crowdsourcing capability influences open innovation performance. Measuring open innovation performance, the authors (p. 419) "asked respondents to report the share of innovation projects where project success was substantially attributable to the integration of external knowledge." Their results are clearly more generalizable in turns of sample size and industry boundaries and, at the same time, inform about the ratio of projects that external knowledge sources can positively influence. However, a higher share of influence on successful innovation projects as a measure of performance does not necessarily imply that Firm A is performing better when their share of successful projects is 80% compared to Firm B with 20%. In fact, the success of the innovation projects by Firm B might be of higher commercial and future value, e.g., because they are more of a radical innovation nature, compared to a higher number of incremental innovation projects by Firm A.

Hence, the insights from testing the first hypothesis in my paper advance our understanding of crowdsourcing not only by focusing on the translation of ideas generated by the crowd into a firm's innovation performance (cf. Bayus 2013, Poetz and Schreier 2012) but also by investigating industry spanning data on the innovation performance, i.e., innovation sales, of firms (cf. Pollok et al. 2019, Nishikawa et al. 2013).

The third contribution relates to my finding that there is a positive interaction effect of crowdsourcing with digital capabilities on a firm's innovation performance. In doing so, I provide evidence for digital capabilities' role in helping firms overcome information-processing challenges related to distant search activities. This is important because neglecting the challenges of distant search may limit the benefits organizations can derive from it. In that sense, I corroborate the notion that digitalization changes how organizations innovate (Nambisan et al. 2019, Yoo et al. 2012) and advance our understanding of external search (Chesbrough 2003, Laursen and Salter 2006), distant search (Katila and Ahuja 2002, March 1991), and crowdsourcing (Afuah and Tucci 2012, Piezunka and Dahlander 2015).

3.8. Concluding remarks and future research

My paper benefits from the inclusion of firms across a variety of industries. However, given that these data are cross-sectional and limited to the data available without the extensive possibilities to merge them with other sources (see Grimpe and Sofka 2009 for a brief discussion on the limitations of CIS data), there are a number of limitations regarding the analysis.

First, the dependent variable, innovation performance, is measured after three preceding years with innovation activity. Although this is in accordance with previous literature (e.g., Cassiman and Valentini 2016, Grimpe and Sofka 2016, Klingebiel and Adner 2015), sales from innovations might take more years to pick up due to potentially slow pace in the diffusion of innovations (Rogers 1995). Thus, it would be promising to collect innovation sales data for multiple successive years after a firm uses crowdsourcing. Such research could also provide more empirical evidence on the issue of reoccurring uses of crowdsourcing (cf. Dahlander and Piezunka 2014) and investigate how digital capabilities as a boundary condition influence this.

Second, other research has suggested that different knowledge sources might be complementary to each other in their relationship with innovation performance (e.g., Grimpe and Sofka 2016). It would be a promising avenue for future research to investigate how the use of other knowledge sources (e.g., universities or competitors) either complements or substitutes the use of crowdsourcing. For example, crowdsourcing might be used to generate novel ideas, but their development into an innovation might benefit from a collaboration with a university. Lastly, my data focus on the innovation activities of German firms. By that nature, the administrative, cultural, and historical environment for all those firms is quite similar. Collecting data and testing my predictions in other large economies, such as the US or Japan, would vary this environment and strengthen the empirical basis for our understanding of the relationship.

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3.10. Tables

Table 17: Digital capabilities items

<table>
<tr><th>Category</th><th>Questions</th><th>Items</th></tr>
<tr><td>Software and databases</td><td>Did your company perform the following software and database activities in 2016-2018?</td><td>• 1: Yes, software programming (in-house or by external parties)
• 2: Yes, purchase of software programs (licenses)
• 3: Yes, development/maintenance of own databases
• 4: Yes, purchase of third-party databases
• 5: Yes, systematic analysis of large amounts of data
• No

[Each item had only one selection possibility.]</td></tr>
<tr><td>Artificial intelligence</td><td>Does your company use artificial intelligence techniques?</td><td>• Yes
• No

If yes, which of the following techniques:

• 6: Speech comprehension
• 7: Image recognition
• 8: Machine learning, machine proving
• 9: Knowledge-based systems
• 10: Other

[Each item could be selected based on the field(s) of application of the respective artificial intelligence technique. The fields of application that could be selected from: i) products, services; ii) process automation; iii) customer communication; iv) data analysis; v) other fields. Multiple fields could be selected.]</td></tr>
</table>

Table 18: Descriptive statistics (N=1,657)

Variables	Mean	S.D.	Min	Max
Sales revenue from new-to-the-market product innovations (log.)	1.554	2.461	0	13.965
Crowdsourcing (d)	0.350	0.477	0	1
Digital capabilities (index)	2.078	1.830	0	10
Crowdsourcing use industry mean	0.350	0.158	0	1
R&D intensity (ratio)	0.091	0.187	0	1
Export intensity (ratio)	0.200	0.290	0	1
No. of employees (log.)	3.628	1.641	0	11.990
Business group (d)	0.366	0.482	0	1
Cooperation (d)	0.457	0.498	0	1

Table 19: Distribution of firms across each level of the digital capabilities index (N=1,657)

Digital capabilities	Frequency	Percentage	Cumulative
0	431	26.01	26.01
1	265	15.99	42.00
2	302	18.23	60.23
3	358	21.61	81.83
4	151	9.11	90.95
5	78	4.71	95.65
6	28	1.69	97.34
7	24	1.45	98.79
8	11	0.66	99.46
9	8	0.48	99.94
10	1	0.06	100.00
Total	1,657	100	

Table 20: Correlation coefficients (N=1,657)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1) Innovation sales (log.)	1.00														
(2) Crowdsourcing (d)	0.10***	1.00													
(3) Digital capabilities (index)	0.27***	0.24***	1.00												
(4) Crowdsourcing use industry mean	0.00	0.33***	0.13***	1.00											
(5) Internal R&D intensity (ratio)	0.11***	0.04+	0.13***	0.06*	1.00										
(6) Export intensity (ratio)	0.28***	-0.00	0.16***	-0.12***	0.09***	1.00									
(7) No. of employees (log.)	0.31***	0.07**	0.34***	-0.06*	-0.20***	0.27***	1.00								
(8) Business group (d)	0.19***	0.03	0.17***	-0.03	-0.11***	0.19***	0.49***	1.00							
(9) Cooperation (d)	0.23***	0.07**	0.22***	0.02	0.31***	0.21***	0.15***	0.10***	1.00						
(10) Low-tech manuf. (d)	0.06**	-0.01	-0.03	-0.02	-0.00	0.05*	0.04	-0.01	-0.01	1.00					
(11) Medium-low-tech manuf. (d)	0.10***	-0.05*	-0.01	-0.16***	0.01	0.24***	0.06*	0.08**	0.11***	-0.16***	1.00				
(12) Medium-high-tech manuf. (d)	0.07**	-0.06*	-0.01	-0.17***	-0.08**	0.19***	0.15***	0.04	-0.00	-0.14***	-0.19***	1.00			
(13) High-tech manuf. (d)	0.03	-0.03	-0.05*	-0.08**	-0.04	0.05*	0.07**	0.00	0.02	-0.06*	-0.09***	-0.07**	1.00		
(14) Less knowledge-int. serv. (d)	-0.02	-0.05*	-0.07**	-0.16***	-0.06*	-0.08**	-0.01	0.02	-0.05+	-0.04	-0.06*	-0.05*	-0.02	1.00	
(15) Knowledge-int. serv. (d)	-0.17***	0.11***	0.10***	0.34***	0.11***	-0.32***	-0.20***	-0.12***	-0.05*	-0.31***	-0.43***	-0.37***	-0.17***	-0.11***	1.00
(16) Other industries	-0.01	-0.01	-0.06*	-0.04	-0.06*	-0.06*	0.02	0.07**	-0.04+	-0.10***	-0.13***	-0.12***	-0.05*	-0.03	-0.26***

Notes. + $p<0.10$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Table 21: Main model predicting the use of crowdsourcing (selection) and the marginal effects for the logarithmic sales revenue from new-to-the-market product innovations (Tobit)

	(1) Selection Crowd-sourcing (d)	(2) Tobit Innovation sales (log.)	(3) Tobit Innovation sales (log.)	(4) Tobit Innovation sales (log.)	(5) Tobit Innovation sales (log.)	(6) Tobit Innovation sales (log.)
Crowdsourcing (d)			0.256*		0.243*	-0.062
			(0.123)		(0.123)	(0.200)
Digital capabilities (index)	0.148***			0.170***	0.136***	0.073
	(0.021)			(0.032)	(0.040)	(0.051)
Crowdsourcing*digital capabilities						0.123*
						(0.061)
R&D intensity (ratio)	-0.006	1.718***	1.629***	1.490***	1.496***	1.489***
	(0.198)	(0.269)	(0.267)	(0.267)	(0.268)	(0.267)
Export intensity (ratio)	-0.016	1.063***	1.044***	0.961***	0.972***	0.975***
	(0.131)	(0.197)	(0.197)	(0.196)	(0.198)	(0.197)
No. of employees (log.)	0.020	0.203***	0.164***	0.130**	0.126**	0.121**
	(0.027)	(0.045)	(0.044)	(0.045)	(0.045)	(0.045)
Business group (d)	-0.027	0.182	0.198	0.183	0.191	0.205
	(0.080)	(0.134)	(0.134)	(0.131)	(0.133)	(0.133)
Cooperation (d)	0.058	0.707***	0.647***	0.638***	0.625***	0.617***
	(0.074)	(0.121)	(0.126)	(0.121)	(0.126)	(0.126)
Crowdsourcing use industry mean	3.075***					
	(0.243)					
Inverse Mills ratio			-0.511**		-0.162	-0.200
			(0.168)		(0.194)	(0.194)
Low-tech manuf. (d)	0.061	0.644**	0.741***	0.759***	0.780***	0.793***
	(0.119)	(0.207)	(0.215)	(0.210)	(0.219)	(0.219)
Medium-low-tech manuf. (d)	0.030	0.444**	0.634***	0.564***	0.624***	0.630***
	(0.103)	(0.162)	(0.168)	(0.162)	(0.165)	(0.165)
Medium-high-tech manuf. (d)	0.035	0.365*	0.563**	0.481**	0.547**	0.544**
	(0.115)	(0.186)	(0.198)	(0.185)	(0.194)	(0.192)
High-tech manuf. (d)	0.106	0.333	0.554	0.555+	0.611+	0.627+
	(0.202)	(0.318)	(0.341)	(0.328)	(0.344)	(0.340)
Less knowledge-int. serv. (d)	0.016	0.409	0.952	0.654	0.828	0.822
	(0.366)	(0.606)	(1.016)	(0.651)	(0.944)	(0.923)
Other industries (d)	0.078	0.246	0.357	0.359	0.386	0.387
	(0.135)	(0.230)	(0.235)	(0.231)	(0.236)	(0.236)
Observations	1,657	1,657	1,657	1,657	1,657	1,657
Pseudo-R2	0.127	0.050	0.055	0.056	0.057	0.058
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Standard errors	Robust	Robust	Bootstrapped	Robust	Bootstrapped	Bootstrapped

Notes. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001; the values in the parenthesis of Models 1, 2, and 4 represent robust standard errors, while those in Models 3, 5, and 6 represent Delta-method standard errors based on 1,000 bootstrapped replications; the baseline industry is knowledge-intensive services.

3.11. Appendix

Appendix 28: OLS robustness check for both, the 1st and 2nd stages

	(1) Selection	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS
Crowdsourcing (d)			0.241*		0.239*	-0.251
			(0.121)		(0.120)	(0.189)
Digital capabilities (index)	0.050***			0.210***	0.172***	0.070
	(0.007)			(0.038)	(0.045)	(0.055)
Crowdsourcing*digital capabilities						0.214**
						(0.076)
R&D intensity (ratio)	-0.008	1.527***	1.421***	1.252***	1.259***	1.247***
	(0.068)	(0.331)	(0.329)	(0.323)	(0.324)	(0.320)
Export intensity (ratio)	-0.005	1.222***	1.208***	1.108***	1.124***	1.133***
	(0.044)	(0.245)	(0.249)	(0.242)	(0.250)	(0.250)
No. of employees (log.)	0.006	0.377***	0.334***	0.292***	0.290***	0.280***
	(0.008)	(0.057)	(0.054)	(0.055)	(0.054)	(0.053)
Business group (d)	-0.006	0.165	0.169	0.163	0.165	0.184
	(0.026)	(0.135)	(0.134)	(0.133)	(0.133)	(0.130)
Cooperation (d)	0.022	0.585***	0.501***	0.497***	0.479***	0.469***
	(0.024)	(0.123)	(0.124)	(0.124)	(0.125)	(0.125)
Crowdsourcing use industry mean	0.936***					
	(0.058)					
Inverse Mills ratio			-2.535***		-0.745	-0.931
			(0.665)		(0.778)	(0.781)
Low-tech manuf. (d)	0.010	0.560**	0.689***	0.690***	0.718***	0.741***
	(0.039)	(0.197)	(0.204)	(0.197)	(0.205)	(0.203)
Medium-low-tech manuf. (d)	0.001	0.364*	0.580***	0.502**	0.564***	0.583***
	(0.033)	(0.164)	(0.173)	(0.164)	(0.171)	(0.170)
Medium-high-tech manuf. (d)	-0.001	0.275	0.513**	0.421*	0.490*	0.489*
	(0.036)	(0.191)	(0.198)	(0.188)	(0.195)	(0.195)
High-tech manuf. (d)	0.020	0.319	0.562+	0.557+	0.611+	0.651*
	(0.066)	(0.336)	(0.338)	(0.327)	(0.336)	(0.329)
Less knowledge-int. serv. (d)	0.051	0.380	0.832	0.618	0.752	0.738
	(0.063)	(0.480)	(0.509)	(0.488)	(0.503)	(0.500)
Other industries (d)	0.023	0.183	0.327	0.330	0.360+	0.364+
	(0.042)	(0.214)	(0.211)	(0.212)	(0.210)	(0.210)
Constant	-0.115**	-0.716***	0.799+	-0.836***	-0.418	-0.098
	(0.036)	(0.180)	(0.450)	(0.176)	(0.533)	(0.538)
Observations	1,657	1,657	1,657	1,657	1,657	1,657
R2	0.151	0.177	0.191	0.197	0.200	0.206
Prob > F	0.000	0.000		0.000		
Prob > chi2			0.000		0.000	0.000
Standard errors	Robust	Robust	Bootstrapped	Robust	Bootstrapped	Bootstrapped

Notes. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001; the values in the parentheses of Models 1, 2, and 4 represent robust standard errors, while those in Models 3, 5, and 6 represent Delta-method standard errors based on 1,000 bootstrapped replications; the baseline industry is knowledge-intensive services; all models are estimated using OLS regressions; coefficients display the marginal effects; the dependent variable in Model 1 is crowdsourcing (d) and Innovation sales (log.) in the remaining Models 2-6.

Appendix 29: Estimations for the marginal effects for the logarithmic sales revenue from new-to-the-market product innovations (Tobit) with a sample split for digital capabilities

	(1) Selection	(2) Tobit Digital capabilities = 0	(3) Tobit Digital capabilities >= 1
Crowdsourcing (d)		0.030	0.311*
		(0.210)	(0.151)
Digital capabilities (index)	0.148***		
	(0.021)		
R&D intensity (ratio)	-0.006	1.520**	1.635***
	(0.198)	(0.464)	(0.327)
Export intensity (ratio)	-0.016	1.037**	1.072***
	(0.131)	(0.349)	(0.237)
No. of employees (log.)	0.020	0.059	0.201***
	(0.027)	(0.072)	(0.054)
Business group (d)	-0.027	0.079	0.221
	(0.080)	(0.214)	(0.167)
Cooperation (d)	0.058	0.693***	0.570***
	(0.074)	(0.179)	(0.148)
Crowdsourcing use industry mean	3.075***		
	(0.243)		
Inverse Mills ratio		-0.330	-0.573*
		(0.284)	(0.239)
Low-tech manuf. (d)	0.061	0.330	0.906***
	(0.119)	(0.297)	(0.253)
Medium-low-tech manuf. (d)	0.030	0.679**	0.536*
	(0.103)	(0.249)	(0.210)
Medium-high-tech manuf. (d)	0.035	0.356	0.606*
	(0.115)	(0.289)	(0.254)
High-tech manuf. (d)	0.106	0.022	0.952*
	(0.202)	(0.627)	(0.471)
Less knowledge-int. serv. (d)	0.016	1.952	-0.423
	(0.366)	(1.901)	(2.675)
Other industries (d)	0.078	0.017	0.573+
	(0.135)	(0.289)	(0.327)
Observations	1,657	431	1,226
Pseudo-R2	0.127	0.074	0.051
Prob > chi2	0.000	0.000	0.000
Standard errors	Robust	Bootstrapped	Bootstrapped

Notes. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001; the values in the parenthesis of Model 1 represents robust standard errors, while those in Models 2 and 3 represent Delta-method standard errors based on 1,000 bootstrapped replications; the baseline industry is knowledge-intensive services, the dependent variable in Model 1 is crowdsourcing (d) and Innovation sales (log.) in the remaining Models 2 and 3; Model 2 estimates the innovation sales (log.) based on that part of the sample that has no level of digital capabilities (i.e., the digital capabilities index equals the value 0), whereas Model 3 shows the estimates for the sample in which firms have at least the value 1 for the digital capabilities index.

Appendix 30: OLS robustness check for both, the 1st and 2nd stages, without including the Inverse Mills Ratio in the 2nd stage

	(1) Selection	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS
Crowdsourcing (d)			0.413***		0.274*	-0.196
			(0.119)		(0.119)	(0.181)
Digital capabilities (index)	0.050***			0.210***	0.194***	0.099*
	(0.007)			(0.038)	(0.038)	(0.047)
Crowdsourcing*digital capabilities						0.209**
						(0.075)
R&D intensity (ratio)	-0.008	1.527***	1.501***	1.252***	1.255***	1.242***
	(0.068)	(0.331)	(0.331)	(0.323)	(0.324)	(0.321)
Export intensity (ratio)	-0.005	1.222***	1.219***	1.108***	1.115***	1.122***
	(0.044)	(0.245)	(0.244)	(0.242)	(0.241)	(0.240)
No. of employees (log.)	0.006	0.377***	0.366***	0.292***	0.291***	0.281***
	(0.008)	(0.057)	(0.056)	(0.055)	(0.054)	(0.053)
Business group (d)	-0.006	0.165	0.166	0.163	0.164	0.182
	(0.026)	(0.135)	(0.135)	(0.133)	(0.133)	(0.130)
Cooperation (d)	0.022	0.585***	0.563***	0.497***	0.489***	0.482***
	(0.024)	(0.123)	(0.123)	(0.124)	(0.124)	(0.124)
Crowdsourcing use industry mean	0.936***					
	(0.058)					
Low-tech manuf. (d)	0.010	0.560**	0.594**	0.690***	0.703***	0.721***
	(0.039)	(0.197)	(0.196)	(0.197)	(0.196)	(0.196)
Medium-low-tech manuf. (d)	0.001	0.364*	0.420*	0.502**	0.529**	0.539***
	(0.033)	(0.164)	(0.165)	(0.164)	(0.164)	(0.162)
Medium-high-tech manuf. (d)	-0.001	0.275	0.336+	0.421*	0.451*	0.441*
	(0.036)	(0.191)	(0.191)	(0.188)	(0.188)	(0.188)
High-tech manuf. (d)	0.020	0.319	0.382	0.557+	0.581+	0.612+
	(0.066)	(0.336)	(0.335)	(0.327)	(0.327)	(0.321)
Less knowledge-int. serv. (d)	0.051	0.380	0.490	0.618	0.672	0.639
	(0.063)	(0.480)	(0.477)	(0.488)	(0.486)	(0.483)
Other industries (d)	0.023	0.183	0.219	0.330	0.342	0.341
	(0.042)	(0.214)	(0.213)	(0.212)	(0.211)	(0.211)
Constant	-0.115**	-0.716***	-0.835***	-0.836***	-0.906***	-0.713***
	(0.036)	(0.180)	(0.185)	(0.176)	(0.181)	(0.171)
Observations	1,657	1,657	1,657	1,657	1,657	1,657
R2	0.151	0.177	0.183	0.197	0.199	0.205
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000

Notes. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001; the values in the parentheses represent robust standard errors; the baseline industry is knowledge-intensive services; the dependent variable in Model 1 is crowdsourcing (d) and Innovation sales (log.) in the remaining Models 2-6; coefficients display the marginal effects.

Appendix 31: Propensity-score matching robustness check

	Innovation sales (log.)
Crowdsourcing (d)	0.439*
	(0.206)
Observations	1,657

Notes. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001; the values in the parentheses represent robust Abadie-Imbens standard errors; the coefficient displays the estimated average treatment effect on the treated (ATET); the minimum number of matches is 1 and the maximum is 8.

Appendix 32: Digital capabilities item exploration models for predicting the marginal effects for the logarithmic sales revenue from new-to-the-market product innovations (Tobit)

	(1)	(2)	(3)	(4)	(5)	(6)
	Tobit Innovation sales (log.)	**Tobit Innovation sales (log.)**	**Tobit Innovation sales (log.)**	**Tobit Innovation sales (log.)**	**Tobit Innovation sales (log.)**	**Tobit Innovation sales (log.)**
Crowdsourcing (d)	-0.021	0.213	0.162	0.259	0.288*	0.179
	(0.210)	(0.189)	(0.200)	(0.177)	(0.124)	(0.131)
Software and databases (index, 0-5)	0.095					
	(0.059)					
Crowd*Software and databases	0.142+					
	(0.081)					
Item 1: Software programming (d)		0.393*				
		(0.153)				
Crowd*Software programming		0.181				
		(0.240)				
Item 2: Purchase of software programs (d)			-0.127			
			(0.152)			
Crowd*Purchase of software programs			0.316			
			(0.246)			
Item 3: Dev./maint. of own databases (d)				0.322*		
				(0.157)		
Crowd*Dev./maint. of own databases				0.107		
				(0.248)		
Item 4: Purchase of third-party databases (d)					-0.043	
					(0.353)	
Crowd*Purchase of third-party databases					0.657	
					(0.442)	
Item 5: Systematic analysis of large data (d)						0.211
						(0.234)
Crowd*Systematic analysis of large data						0.523+
						(0.296)
Inverse Mills ratio	-0.136	-0.079	-0.142	-0.157	-0.148	-0.175
	(0.199)	(0.199)	(0.194)	(0.194)	(0.189)	(0.193)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,657	1,657	1,657	1,657	1,657	1,657
Pseudo-R2	0.057	0.056	0.053	0.055	0.054	0.056
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Standard errors	Bootstrap	Bootstrap	Bootstrap	Bootstrap	Bootstrap	Bootstrap

Notes. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001; the table excludes the first stage selection results and only shows the second stage results; the values in the parenthesis represent Delta-method standard errors based on 1,000 bootstrapped replications; industry variables are included in each model (low-tech manufacturing, medium-low-tech manufacturing, medium-high-tech manufacturing, high-tech manufacturing, less knowledge-intensive services, and knowledge-intensive services), the baseline industry is knowledge-intensive services; controls are included in each model (R&D intensity, export intensity, number of employees, business group, and cooperation); the software and databases index variables sums up the Items 1-5 dummies (it takes on the value 0 if a firm used none of the software and databases items and 5 if a firm used all of the software and databases items).

Appendix 32 continued

	(7) Tobit Innovation sales (log.)	(8) Tobit Innovation sales (log.)	(9) Tobit Innovation sales (log.)	(10) Tobit Innovation sales (log.)	(11) Tobit Innovation sales (log.)	(12) Tobit Innovation sales (log.)
Crowdsourcing (d)	0.342**	0.218+	0.263*	0.286*	0.366**	0.228+
	(0.120)	(0.124)	(0.124)	(0.122)	(0.118)	(0.127)
Artificial intelligence (index, 0-5)	0.046					
	(0.136)					
Crowd*Artificial intelligence (index)	0.252+					
	(0.152)					
Item 6: AI speech comprehension (d)		0.292				
		(0.470)				
Crowd*AI speech comprehension		0.120				
		(0.578)				
Item 7: AI image recognition (d)			0.083			
			(0.270)			
Crowd*AI image recognition			1.059**			
			(0.355)			
Item 8: AI machine learning (d)				-0.356		
				(0.365)		
Crowd*AI machine learning				0.908*		
				(0.437)		
Item 9: AI knowledge-based systems (d)					0.375	
					(0.379)	
Crowd*AI knowledge-based systems					0.381	
					(0.442)	
Item 10: AI other (d)						1.575***
						(0.185)
Crowd*AI other						-1.263
						(4.390)
Inverse Mills ratio	-0.156	-0.138	-0.169	-0.159	-0.151	-0.149
	(0.194)	(0.195)	(0.190)	(0.194)	(0.191)	(0.192)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,657	1,657	1,657	1,657	1,657	1,657
Pseudo-R2	0.053	0.057	0.054	0.055	0.053	0.056
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Standard errors	Bootstrap	Bootstrap	Bootstrap	Bootstrap	Bootstrap	Bootstrap

Notes. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001; the table excludes the first stage selection results and only shows the second stage results; the values in the parenthesis represent Delta-method standard errors based on 1,000 bootstrapped replications; industry variables are included in each model (low-tech manufacturing, medium-low-tech manufacturing, medium-high-tech manufacturing, high-tech manufacturing, less knowledge-intensive services, and knowledge-intensive services), the baseline industry is knowledge-intensive services; controls are included in each model (R&D intensity, export intensity, number of employees, business group, and cooperation); the artificial intelligence index variables sums up the Items 6-10 dummies (it takes on the value 0 if a firm used none of the artificial intelligence items and 5 if a firm used all of the artificial intelligence items).

Appendix 33: Predicting the use of crowdsourcing (selection) and the marginal effects for the logarithmic sales revenue from new-to-the-market product innovations (Tobit) in the *manufacturing* industry

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	Selection Crowd-sourcing (d)	**Tobit Innovation sales (log.)**	**Tobit Innovation sales (log.)**	**Tobit Innovation sales (log.)**	**Tobit Innovation sales (log.)**	**Tobit Innovation sales (log.)**
Crowdsourcing (d)			0.370+		0.326	-0.509
			(0.218)		(0.213)	(0.340)
Digital capabilities (index)	0.146***			0.252***	0.275***	0.118
	(0.031)			(0.054)	(0.066)	(0.082)
Crowdsourcing*digital capabilities						0.341***
						(0.101)
R&D intensity (ratio)	0.090	1.920***	1.751**	1.531**	1.561**	1.549**
	(0.356)	(0.539)	(0.565)	(0.522)	(0.534)	(0.526)
Export intensity (ratio)	-0.092	1.011**	1.035***	0.879**	0.855**	0.834**
	(0.175)	(0.311)	(0.308)	(0.310)	(0.309)	(0.307)
No. of employees (log.)	0.034	0.280***	0.242**	0.175*	0.178*	0.159*
	(0.040)	(0.078)	(0.078)	(0.077)	(0.076)	(0.074)
Business group (d)	0.018	0.249	0.275	0.251	0.249	0.278
	(0.119)	(0.229)	(0.230)	(0.221)	(0.225)	(0.218)
Cooperation (d)	0.062	0.908***	0.888***	0.842***	0.846***	0.810***
	(0.106)	(0.200)	(0.199)	(0.197)	(0.196)	(0.193)
Crowdsourcing use industry mean	3.517***					
	(0.465)					
Inverse Mills ratio			-0.290		0.350	0.233
			(0.265)		(0.311)	(0.312)
Observations	755	755	755	755	755	755
Pseudo-R2	0.103	0.040	0.043	0.048	0.050	0.054
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Standard errors	Robust	Robust	Bootstrapped	Robust	Bootstrapped	Bootstrapped

Notes. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001; the values in the parenthesis of Models 1, 2, and 4 represent robust standard errors, while those in Models 3, 5, and 6 represent Delta-method standard errors based on 1,000 bootstrapped replications; the baseline industry is knowledge-intensive services.

Appendix 34: Predicting the use of crowdsourcing (selection) and the marginal effects for the logarithmic sales revenue from new-to-the-market product innovations (Tobit) in the *service* industry

	(1)	(2)	(3)	(4)	(5)	(6)
	Selection Crowd-sourcing (d)	**Tobit Innovation sales (log.)**	**Tobit Innovation sales (log.)**	**Tobit Innovation sales (log.)**	**Tobit Innovation sales (log.)**	**Tobit Innovation sales (log.)**
Crowdsourcing (d)			0.188		0.186	0.182
			(0.145)		(0.145)	(0.240)
Digital capabilities (index)	0.150***			0.091*	0.030	0.029
	(0.029)			(0.040)	(0.049)	(0.067)
Crowdsourcing*digital capabilities						0.002
						(0.078)
R&D intensity (ratio)	-0.052	1.398***	1.378***	1.292***	1.346***	1.346***
	(0.243)	(0.280)	(0.274)	(0.279)	(0.278)	(0.280)
Export intensity (ratio)	-0.003	0.722**	0.714**	0.645*	0.690*	0.690*
	(0.230)	(0.276)	(0.276)	(0.276)	(0.276)	(0.279)
No. of employees (log.)	-0.001	0.131*	0.115*	0.091	0.104+	0.104+
	(0.040)	(0.056)	(0.057)	(0.057)	(0.059)	(0.059)
Business group (d)	-0.017	0.060	0.030	0.060	0.035	0.035
	(0.117)	(0.169)	(0.165)	(0.168)	(0.166)	(0.165)
Cooperation (d)	0.098	0.651***	0.543***	0.601***	0.544***	0.544***
	(0.111)	(0.152)	(0.155)	(0.155)	(0.155)	(0.156)
Crowdsourcing use industry mean	2.731***					
	(0.307)					
Inverse Mills ratio			-0.471*		-0.382	-0.383
			(0.220)		(0.267)	(0.267)
Observations	777	777	777	777	777	777
Pseudo-R2	0.127	0.042	0.048	0.045	0.048	0.048
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Standard errors	Robust	Robust	Bootstrapped	Robust	Bootstrapped	Bootstrapped

Notes. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001; the values in the parenthesis of Models 1, 2, and 4 represent robust standard errors, while those in Models 3, 5, and 6 represent Delta-method standard errors based on 1,000 bootstrapped replications; the baseline industry is knowledge-intensive service.

Appendix 35: Predicting the use of crowdsourcing (selection) and the marginal effects for the logarithmic sales revenue from new-to-the-market product innovations (Tobit) in *other* industries

	(1) Selection Crowd-sourcing (d)	(2) Tobit Innovation sales (log.)	(3) Tobit Innovation sales (log.)	(4) Tobit Innovation sales (log.)	(5) Tobit Innovation sales (log.)	(6) Tobit Innovation sales (log.)
Crowdsourcing (d)			0.150		0.115	0.375
			(0.417)		(0.417)	(0.598)
Digital capabilities (index)	0.223*			0.281*	0.265+	0.325+
	(0.092)			(0.112)	(0.139)	(0.180)
Crowdsourcing*digital capabilities						-0.125
						(0.213)
R&D intensity (ratio)	-1.708	1.472	1.457	0.814	0.842	0.687
	(1.049)	(1.183)	(2.144)	(1.052)	(1.953)	(1.957)
Export intensity (ratio)	-0.007	3.244***	3.127***	3.077***	3.035***	3.123***
	(0.666)	(0.785)	(0.836)	(0.764)	(0.836)	(0.870)
No. of employees (log.)	0.052	0.103	0.053	-0.042	-0.056	-0.049
	(0.114)	(0.136)	(0.148)	(0.137)	(0.149)	(0.151)
Business group (d)	-0.297	0.500	0.609	0.506	0.555	0.545
	(0.297)	(0.407)	(0.437)	(0.398)	(0.433)	(0.440)
Cooperation (d)	-0.338	-0.341	-0.234	-0.473	-0.420	-0.385
	(0.302)	(0.441)	(0.503)	(0.448)	(0.527)	(0.532)
Crowdsourcing use industry mean	4.722***					
	(0.998)					
Inverse Mills ratio			-0.258		-0.094	-0.082
			(0.358)		(0.374)	(0.381)
Observations	125	125	125	125	125	125
Pseudo-R2	0.226	0.079	0.083	0.095	0.096	0.097
Prob > chi2			0.150		0.115	0.375
Standard errors	Robust	Robust	Bootstrapped	Robust	Bootstrapped	Bootstrapped

Notes. + p<0.10, * p<0.05, ** p<0.01, *** p<0.001; the values in the parenthesis of Models 1, 2, and 4 represent robust standard errors, while those in Models 3, 5, and 6 represent Delta-method standard errors based on 1,000 bootstrapped replications; the baseline industry is knowledge-intensive services.

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