Center for European, Governance and Economic Development Research
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Discussion Papers

Number 251 – June 2015

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ISSN: 1439-2305

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Abstract:
Economic research on innovation has long discussed which policy instruments best foster innovativeness in individuals and organizations. One of the instruments easily accessible to policy-makers is innovation contests; however, there is ambiguous empirical evidence concerning how such contests should be designed. Our experimental study provides evidence by analyzing the effects of two different innovation contests on subjects' innovativeness: a prize for the aggregate innovativeness and a prize for the best innovation. We implement a creative real effort task simulating a sequential innovation process, whereby subjects determine royalty fees for their created products, which also serve as a measure of cooperation. We find that both contest conditions reduce the willingness to cooperate between subjects compared to a benchmark condition without an innovation contest. However, the total innovation activity is not influenced by introducing innovation contest schemes. From a policy perspective, the implementation of state-subsidized innovation contests in addition to the existing intellectual property rights system should be questioned.

Keywords: innovation prizes, competition, laboratory experiment, real effort task, creativity, innovation policy
JEL-Classification: C91, D89, O31

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1. Introduction

Innovations are considered the driving force for economic growth in modern economies, prompting governments to stimulate private and public innovation activities. Most recently, the European Union announced increasing investment in R&D to three percent of GDP by 2020 and – in a similar effort – the United States legislated the "America COMPETES Reauthorization Act" to improve their competitiveness by boosting R&D (COM(2010) 2020; H.R.5116). Policy-makers can draw upon three categories of instruments to implement such strategies: regulatory instruments such as intellectual property rights, economic and financial regulations such as subsidies or tax exemptions and soft instruments such as voluntary agreements (Bemelmans-Videc et al. 1998; Borrás and Edquist 2013). The determination of states to increase domestic innovativeness has initiated a large research debate, discussing how to best combine these instruments to achieve an effective policy mix (Flanagan et al. 2011; Guerzoni and Raiteri 2015).[1]

Innovation contests are one of the most frequently discussed financial regulatory instruments, commonly modeled as a competitive game with one or more players investing to create innovations (Kremer and Williams 2010; Adler 2011; Clancy and Moschini 2013).[2] Economic research has analyzed innovation contests with respect to design specifics and their potential outcome by considering e.g. single or multiple solvers and prizes, its duration and – most prominently – its incentive structure (Adamczyk et al. 2012; Williams 2012). The distinct design of incentive structures analyzed comprise e.g. ex-post prizes rewarding previous work (Moser and Nicholas 2013) or ex-ante prizes with unknown outcome (Murray et al. 2012), as well as proportional prize contests, whereby the prize is granted relative to participants' achievements (Cason et al. 2010).

Numerous theoretical and empirical contributions have aimed at deriving policy implications for the most efficient design of innovation contests. However, empirical research shows ambiguous findings concerning the impact of innovation contests (Boudreau et al. 2011; Brunt et al. 2012; Nicholas 2013). Similarly, there are mixed results developed in theoretical contributions (Wright 1983; Taylor 1995; Moldovanu and Sela 2001; Che and Gale 2003; Ganuza and Hauk 2006; Cohen et al. 2008; Schöttner 2008; Chari et al. 2012). We contribute to this unresolved debate by presenting novel empirical evidence from a laboratory experiment and derive policy implications for the optimal design of innovation contests.

[1] For a broader literature overview regarding the effect of public subsidies on innovativeness, see Zúñiga-Vicente et al. (2014) and David et al. (2000); a similar study on the effect of taxes is provided by Hall and Reenen (2000). For an overview of the necessity of subsidizing innovations from a financial market perspective, see Hall and Lerner (2010).

[2] See Williams (2012) and Adamczyk et al. (2012) for a review on the current literature on innovation contests.

We follow an experimental approach to overcome some shortcomings of previous research in evaluating the effects of various contest schemes on innovativeness. Empirical research relying on field data is bound to data availability and thus a profound analysis across contest schemes is not feasible. Economic experiments allow generating data that enables a ceteris paribus comparison of different contest schemes (Blasio et al. 2014). Therefore, we would argue along with Sørensen et al. (2010) that economic experiments are "a promising approach" (Sørensen et al. 2010, 313) and a fruitful methodological addition to the existing innovation research.

Based upon this notion, experimental studies can analyze the effects of different policy instruments e.g. by simulating sequential innovation processes (Cantner et al. 2009; Meloso et al. 2009; Buchanan and Wilson 2014). Dealing with innovation in laboratory experiments necessarily induces a trade-off between simulating the complex interactions of creative and dynamic sequential innovation processes accurately and keeping the task manageable for participants. While this obviously places certain limits upon the external validity of an experimental approach, we are confident that we are able to achieve a meaningful analysis of innovation contests in our setting, given that we implement the key features of actual innovation settings like risky investment choices and creativity. Therefore, we build upon a prior setting, investigating the effects of introducing intellectual property rights for innovations, whereby subjects are rewarded for their innovativeness and are able to license their innovations by demanding royalty fees (Crosetto 2010; Brüggemann et al. 2014).

However, in our analysis, we focus on two specific types of innovation contests, implementing (1) a prize for the aggregate innovativeness and (2) a prize for the best innovation. According to a between-subject design, the two treatments are subsequently compared to (3) a benchmark treatment without an innovation contest. All treatments include the possibility to license innovations that allow measuring cooperation behavior and only differ with respect to the payment structure. Particularly for investigating the effects of a prize for the aggregate innovativeness, we implement a contest with a relative payoff-scheme disproportionally rewarding the most innovative subject. In the treatment with the prize for the best innovation, subjects are paid proportionally for each innovation while an additional bonus is awarded to the subject who has created the most valuable innovation. In the benchmark treatment, subjects are merely paid proportionally to their innovations. This experimental set-up allows us to test for the specific effects of introducing innovation contests on individual creativity and innovation performance, as well as concerning how cooperation among innovators evolves with and without contest schemes.

We find that both types of innovation contests – the prize for the aggregate innovativeness and the prize for the best innovation – reduce the willingness to cooperate as measured by the average royalty fees demanded. However, the actual cooperation does not decrease, as subjects tend to accept the higher royalty fees to build upon other subjects' previous innovations to win the innovation contest. With respect to innovativeness, our results indicate that neither a prize for the aggregate innovativeness nor a prize for the best innovation have a positive overall impact. Therefore, our behavioral evidence suggests that both types of contests investigated cannot unambiguously be recommended as effective policy instruments due to welfare concerns. This becomes apparent when considering potential distortions to generate the revenue to spend on innovation contests and diminished cooperation among innovators.

The remainder of this paper is organized as follows. Section two reviews the related literature, before section three outlines our experimental design and hypotheses. Section four presents our results and section five concludes.

2. Literature Review

There is a large body of literature dealing with the effects of innovation contests. Williams (2012) reviews this literature with a focus on innovation prizes in the United States, emphasizing the importance of both estimating an appropriate size of prizes and considering the sequentiality of innovations for spurring subsequent innovations. Williams claims that additional research on the effectiveness of prizes and the specific construction of prize designs is required. Adamczyk et al. (2012) review the current literature on innovation contests by drawing upon the distinct perspectives from economic, management, education, innovation and sustainability research. From an economic research perspective, they point out that more innovators will participate in contests if there is a high monetary award. Similar to Williams (2012), they suggest that further research should focus on the particular design of innovation contests. Clancy and Moschini (2013) provide an overview of different financial regulation instruments to foster innovation. They state that innovation contests can potentially overcome deadweight losses caused through the monopoly rights of patents and moral hazard problems of contracted research. Comparing the different instruments, they claim that a hybrid system in which innovators can choose to receive either a patent or a prize is superior to a pure patent system in terms of output.[3]

[3] For further reviews on innovation prizes, see Gallini and Scotchmer (2002) and Maurer and Scotchmer (2004).

A number of theoretical studies consider the optimal design of innovation contests, yielding ambiguous implications. Taylor (1995) models innovation contests with homogeneous contestants, showing that restricting the entry may be beneficial for the contest designer. Wright (1983) investigates patents, prizes and contracts as rewards for winning innovation contests, finding advantages of patents over prizes due to private information. Comparing a contest comprising multiple prizes with a contest offering a single prize, Moldovanu and Sela (2001) find that the latter leads to an optimal allocation of resources. Ganuza and Hauk (2006) study vertical and horizontal competition in contests, finding multiple equilibria. Cohen et al. (2008) analyze the design of innovation contests and their potential of maximizing either the overall or the maximum effort, finding that the optimal prize can both increase and decrease participants' effort. Comparing a first-price auction with a fixed-prize tournament in innovation contests, Schöttner (2008) suggests that the latter is superior.

Furthermore, there are some empirical studies on the effects of specific innovation prizes, which also show mixed evidence. Murray et al. (2012) investigate the ex-ante influence of the Progressive Automotive Insurance X PRIZE as an example of a grand innovation prize. Boudreau et al. (2011) analyze the results of a computer programming contest with respect to the size of the participant pool on individual effort levels. If more competitors are permitted, the aggregate innovativeness will decrease, while the probability of a high valued innovation increases. Nicholas (2013) examines the effectiveness of innovation prizes in Japan's Meiji era, finding strong evidence that prizes lead to a substantial boost of new patents. Relying on a similar approach, Brunt et al. (2012) estimate an substantial increase in patenting activities in the Royal Agricultural Society of England between 1839 and 1939 due to innovation prizes.

Another methodological approach to empirically investigate innovation prizes is to conduct economic experiments.[4] There are few studies relying on a search task to imitate the innovation process. In a field experiment, Boudreau and Lakhani (2012) discover the impact of different types of innovation prizes by allowing subjects to choose between competitive and cooperative regimes. In comparison to a benchmark treatment, the problem-solving performance almost doubled in the competitive regime and increased by one-third in the cooperative regime when subjects could choose their preferred institutional setting. Using a

[4] A large body of experimental research deals with the question of the best incentive structure in contests focusing on investment and organizational structures, while excluding the innovative part of the process. For an overview on winner-takes-it-all and rank-order tournaments with fixed prizes, see Irlenbusch (2006). Fullerton et al. (1999) test the predictions of Taylor's search model of tournaments, finding that R&D contests achieve very high levels of efficiency in the laboratory and that the level of research effort tends to be close to the theoretical predictions. Comparing a winner-takes-it-all-contest with a proportional-payment design, Cason et al. (2010) find more entries and higher total achievement in the proportional-payment scheme, as a single very capable player often dejects other participants in the winner-takes-it-all scheme.

word task, Eckartz et al. (2012) identify only very small effects of different payment schemes, given that subjects were intrinsically motivated by the self-rewarding task. Furthermore, analyzing exploration behavior and risk aversion under different payment schemes, Ederer and Manso (2013) present a searching task in a multi-dimensional space. They find that a combination of tolerance for early failure and rewards for long-term success are effective in fostering innovation. Buchanan and Wilson (2014) use a search task similar to Ederer and Manso (2013) to simulate intellectual property and additionally provide subjects with the option to produce a non-creative good. When intellectual property is available to subjects, the creation of non-rivalrous innovation knowledge goods is greatest. However, prices increase as substantial monopoly profits are acquired by the innovators. In the absence of intellectual property rights, subjects still create non-rivalrous innovations, although they also resort to intellectual property theft from other subjects. Rijnsoever et al. (2012) examine the influence of an environmental change on innovative behavior, whereby subjects have to make a risky investment decision over several periods to achieve a second stage with a prize contest and environmental change. In a second study, the measure of innovative behavior was transferred to a business context. The authors find support for a U-shaped relationship between economic status and innovative behavior in both cases.

By choosing to implement non-creative real effort search tasks, the experiments reviewed above tend to exclude the creativity required in an innovation process. However, transferring this immanent feature of the innovation process to the lab might be crucial to achieve meaningful results at a satisfactory level of external validity. Only few papers implement creativity tasks to more closely simulate innovation processes to examine the influence of incentive structures on innovativeness. Bradler (2015) compares the incentives of a tournament with a fixed payment scheme for a creative task, finding support for self-selection into tournaments according to risk attitudes and self-assessments, yet no such effect for creative productivity. Crosetto (2010) presents experimental evidence on innovation behavior in the presence of intellectual property rights, including open source. The author introduces a real effort word creation task in which subjects – similar to the board game *Scrabble* – innovate by creating and extending words. Crosetto's results suggest that open source only emerges in treatments with high royalty fees rather than low ones, although high royalty fees tend to foster anticommons effects. Building upon this study and introducing endogenous license fees, Brüggemann et al. (2014) show that overall innovativeness increases in a setting without intellectual property rights.

We contribute to the literature reviewed above by implementing such a real effort word creation task to research into the effects of introducing varying incentive schemes for

innovations. In particular, we are interested in two types of innovation contests: (1) a prize for the aggregate innovativeness and (2) a prize for the best innovation.

3. Experimental Design

3.1. Design

Many features determine the outcomes of an innovation contest, e.g. the available information and the number of participants. However, in our study, we concentrate on one crucial feature, namely the external incentive scheme designed by public policy-makers to foster innovativeness and eventually cooperation among competitors. Our basic framework implements a real effort word creation task, representing a sequential innovation setting with the possibility to license innovations. This basic framework is based upon Crosetto (2010) and Brüggemann et al. (2014) and is modified to test for the effects of a prize for the aggregate innovativeness and a prize for the best innovation.

To implement task characteristics like creativity and to account for the subjects' different skills, we recreate the board game *Scrabble* for our laboratory experiment. Therefore, subjects can earn a certain payoff by creating words from letters, which they can buy from the experimenter. They have the option to determine license fees for produced words, which can be extended in the following, thus representing the sequentiality of the innovation process. Thus, subjects have to act strategically and creatively by facing both an investment decision (buying new letters) as well as the real effort task of building words from randomly assigned letters. The game is played by groups of 4 randomly matched subjects. The group composition remains constant throughout the 25 periods of the game. The initial endowment for each subject comprises 75 experimental tokens and 4 randomly pre-selected letters.[5]

In all treatments, subjects can take three actions upon each turn: first, deciding to invest by buying a letter; second, producing a word; and third, choosing a royalty fee.

Investment phase

Initially, a subject has to decide whether to buy a random letter for a fixed price of 2 tokens. The letter set comprises 191 letters, whose valuation is determined by the inverse of a letter's frequency in the set, leading to an average letter value of 1.87. Therefore, buying a letter potentially leads to negative returns, as a letter's price is somewhat above its average value. The letters are allocated randomly to the subjects, although the sequence of letters given out is

[5] The English translation of the original German experimental instructions is provided in appendix A, including a screenshot of the main board and the details of the letterset.

predetermined and fixed for all groups, which makes the action sets across groups more comparable.

Production phase

Following the investment phase, the respective subject chooses to produce a three-letter word (*root*), extend an existing word (*extension*) or pass and do nothing in the respective period. When building an extension, a subject is only allowed to extend an existing word with one additional letter, which can be placed in any position of the existing word. For instance, if a subject owns the letters *a*, *d*, *i* and *p*, she can create the roots *aid* or *dip*.[6] For example, *aid* can be extended to *paid*, *maid* or *arid*, while *arid* can then be extended into *acrid* and so on. All produced words yield a payoff equal to the sum of the letter values, although a word can only be produced once. Accordingly, longer words tend to be more valuable. When extending a word, not only the one letter added but rather all letters of the new word generate payoff. For instance, extending *arid* (worth 1+1+1+1=4 tokens) into *acrid* with the letter *c* – which itself is worth 4 tokens – results in a payoff of 8 tokens.

Royalty phase

After having created a root or an extension, each subject is able to determine a royalty fee. A royalty fee for an extension only refers to the one letter added. Royalty fees range from 0% to 100% in steps of 10%. The chosen royalty fee becomes public information and is fixed for the rest of the game. However, no one can be excluded from using the word altogether. By choosing higher royalty fees, subjects earn more when their word creations are extended by other subjects. Nevertheless, at the group level, royalty fees are merely a mechanism of redistributing income as there are no transaction costs.

For example, subject A produces *aid* – worth 3 tokens – and chooses a royalty fee of 40%. Every subject who extends *aid* pays A 1.2 tokens. Consider subject B extending *aid* into *paid*, which is worth 7 tokens: 1.2 tokens are transferred to subject A, subject B earns 5.8 tokens and has to set a royalty fee for the letter *p*, worth 4 tokens. If she chooses 50%, the next subject adding a letter to the word *paid* will have to pay 1.2 tokens to subject A and 2 tokens (50% of 4 tokens, namely the value of the letter *p*) to subject B. In order to keep the decision for subjects simple, the amount of royalty fees incurred by using a word is always presented to subjects on the main board (see appendix A).

[6] For an easier understanding, we report the following examples in English, although the experiment was run in German.

When subjects are not at turn, the main board of the game is shown. On this board, subjects are shown their payoffs so far, they can observe the actions of their group members and are able to come up with their next word creations using the list of extendable public words, their own letters and testing new creations with an interactive spellchecker. The spellchecker can be used without restriction to check whether a word is accepted in the game. A word is accepted when it is included in the MS Windows dictionary implemented in the game. The list of public words comprises all words produced in the respective group thus far. Furthermore, the information on the value of these public words, the respective amount of royalty fees and the respective owner of the word is documented.

3.2. Treatment conditions and experimental procedure

We implement a between-subject design with three treatments, as shown in table 1.

Table 1. Overview of the treatment conditions

treatment	Variation		number of participants
	prize for the aggregate innovativeness	prize for the best innovation	
control	no	No	48
ranking	yes	No	48
bonus	no	Yes	48

In *control*, accumulated tokens are converted by an exchange rate of 1 token to €0.12 at the end of the game.[7] In *ranking,* subjects are paid relative to the performance of the other group members and receive a prize for their aggregate innovativeness. The subject who has accumulated the most tokens at the end of the game receives €24, while the other three group members receive a show-up fee of €12 each.[8] Accordingly, in *ranking*, an additional box showing the current ranking is displayed on the main board, which allows subjects to constantly evaluate their performance. In *bonus,* the payoff is the same as in *control*, aside from a €10 bonus awarded to the subject building the most valuable word and thus for the best innovation. Precisely, this means that the subject adding the last letter to the word with

[7] Please note that we used the data of the treatment *noChat/IP* from Brüggemann et al. (2014) as our *control* treatment. Both experiments have been conducted in the same laboratory and the recruitment of subjects was from the same pool of student participants; however, no subject was allowed to participate in both experiments.

[8] In case two or more players had the same number of tokens and all were ranked first, each player would have received €24. Therefore, it would have been possible for all players to do nothing and receive €24; however, this did not occur.

the highest value receives an additional €10.[9] Similar to *ranking*, an additional box on the main board displays a list of all subjects' current most valuable words. To provide an additional control variable for individual creativity, we implemented an incentivized word-finding control task before starting the main task.[10]

Experiments were conducted in the Laboratory for Behavioral Economics at the University of Göttingen. Participants were recruited using ORSEE (Greiner 2004) and were allowed to participate in one session only, which lasted around 90 minutes. The 13 sessions for *control* took place in August and September 2013. In February, March and April 2014, we conducted the sessions for *ranking* and *bonus* with 144 subjects in total. To successfully participate in the experiment, subjects necessarily have to speak German well. Therefore, we carried out the same language test as Kirchkamp and Reiß (2011), thus essentially excluding non-native speakers.[11] Participants were on average 23.7 years old and 48.6% were female, with 37.5% being students of economics. On average, each participant earned €16 in sessions lasting around 90 minutes, with a minimum payoff of €5.9 and a maximum of €32.4.

3.3. Hypotheses

Overall innovativeness – which we define as the aggregate value created in the game by building words – will decline over the course of the game if subjects merely build roots due to the lower expected value of a letter (1.87 tokens) when compared to its cost (2 tokens). Thus overall innovativeness only increases when subjects build extensions and re-use existing words. Therefore, cooperation among participants – i.e. the tendency to make use of others' innovations, as well as not trying to exclude others from one's own innovations – might be crucial for aggregate welfare.

Our first hypothesis applies two different measures of cooperation: the demanded royalty fees and the extensions created from other subjects' roots. Subjects demanding low royalty fees for their roots foster the production of additional extensions. This can be interpreted as willingness to cooperate, which may increase groups' overall innovativeness. However, at an individual level, it might be reasonable to set high royalty fees to generate additional income from creating innovations. In turn, at the group level, this might have a detrimental effect as subjects could cease using other subjects' words to avoid paying royalty fees and to build more roots. These considerations emphasize the game's inherent social dilemma character in

[9] In case two players achieve the same highest value – which did not occur in any case – both would have been rewarded the bonus.

[10] The instructions for the word task can be found in appendix B, the results in appendix C.

[11] The participants had to find the correct word or form to complete a sentence. Those who failed the language test on more than two out of 10 items were not allowed to participate.

the presence of royalty fees, which might affect overall innovativeness, i.e. the ratio of basic *(roots)* and more sophisticated innovations *(extensions)*.

Therefore, we interpret the level of royalty fees chosen by subjects as the willingness to cooperate, whereas the number of extensions of other subjects' words can be understood as the level of actual cooperation. The willingness to cooperate shows potentially adverse effects of the competition framework implemented in *ranking* and *bonus*. Previous findings in both the innovation contest and the experimental literature point to decreasing cooperation due to competitive settings (Boudreau et al. 2011; Chaudhuri 2011). We thus assume increased competition with a prize for the aggregate innovativeness (*ranking)* and a prize for the best innovation (*bonus)* to lower the willingness to cooperate, as measured by higher royalty fees demanded. Furthermore, we expect a decrease in actual cooperation measured by the frequency of using other subjects' words in both innovation contests, namely *ranking* and *bonus.*

Hypothesis 1 ("Competition and cooperation")

a) The willingness to cooperate is lower in *ranking* and *bonus*.
b) The actual cooperation is lower in *ranking* and *bonus*.

Our second hypothesis addresses the effect of contest schemes on innovativeness. There is no clear consensus within the innovation literature regarding which design of an innovation contest best fosters innovativeness (Williams 2012). However, based upon previous studies pointing to rather positive effects of innovation contests on innovativeness (Brunt et al. 2012; Nicholas 2013), we hypothesize that the total innovation activity will increase given a contest scheme. Accordingly, we formulate the following:

Hypothesis 2 ("Innovation activity")

Total innovation activity increases in *ranking* and *bonus*.

4. Results

We first analyze the effects of introducing an innovation contest on the willingness to cooperate and actual cooperation, before subsequently investigating overall innovativeness. We finally check the robustness of our results against the actual choice set by introducing a

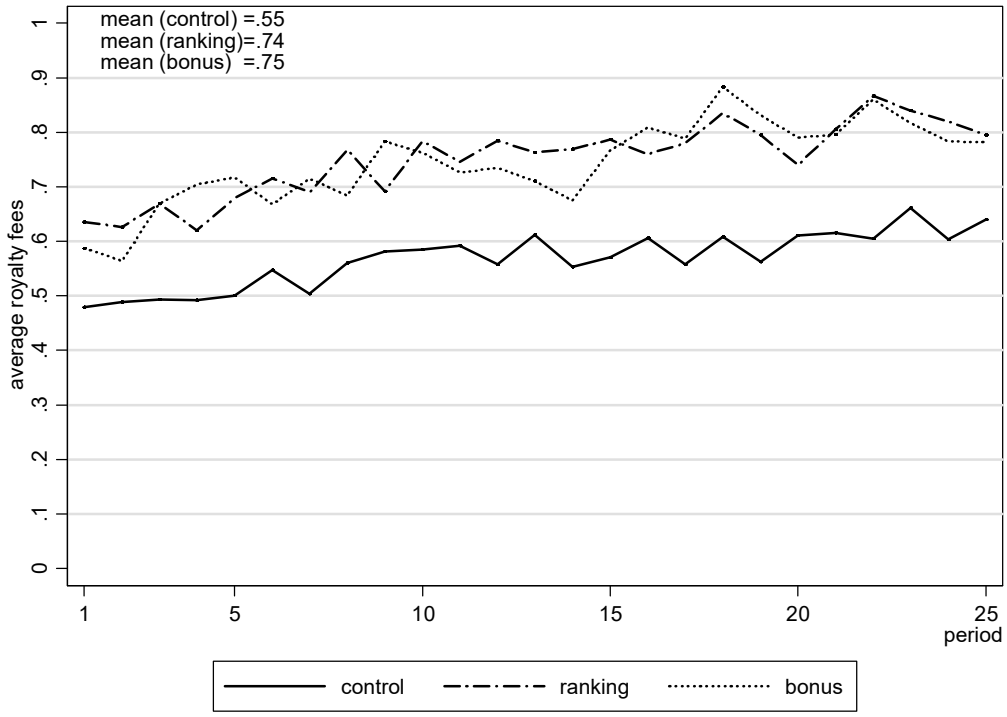
measure providing the degree to which individuals were able to exploit their specific opportunities of producing words in each period.[12]

4.1. Competition and cooperation

4.1.1. Willingness to cooperate

For all treatments, the game allows subjects to license their innovations by demanding royalty fees between 0% and 100%. Royalty fees can be interpreted as a measure of cooperation as they give the prices for building upon others' prior innovations. Subjects who are reluctant to cooperate will ask for higher royalty fees, while those interested in cooperation choose lower fees and might expect some reciprocal behavior. Remember that letters induce costs when they are bought but can be reused several times, which generates an income premium for cooperation, i.e. a surplus at the group level. Put simply, at lower royalty fees, subjects might be more willing to build upon the same words several times and thus create more sophisticated innovations, which benefits the whole group. Figure 1 illustrates the average royalty fees demanded by treatment.

Figure 1. Royalty fees demanded by treatment



For all treatments, there is an upward trend in royalty fees demanded, which connects well to the findings of the public good experiment literature, typically identifying decreasing

[12] Note that we can rule out the notion that treatment differences are driven by a particular distribution of task specific knowledge due to the results of our control task (appendix C).

cooperation over time (Chaudhuri 2011). However, royalty fees demanded are lowest in *control* (Mann-Whitney test: *control* vs. *ranking* z=-2.136 and p=.0327; *control* vs. *bonus* z=-2.194 and p=.0282)[13], whereby the difference amounts to about 20 percentage points and is constant over time.

RESULT 1: *There is strong evidence in support of H1a. While the royalty fees demanded gradually increase over time for all payment schemes, there is a substantial downward shift in the willingness to cooperate when introducing innovation contests.*

4.1.2. Actual cooperation

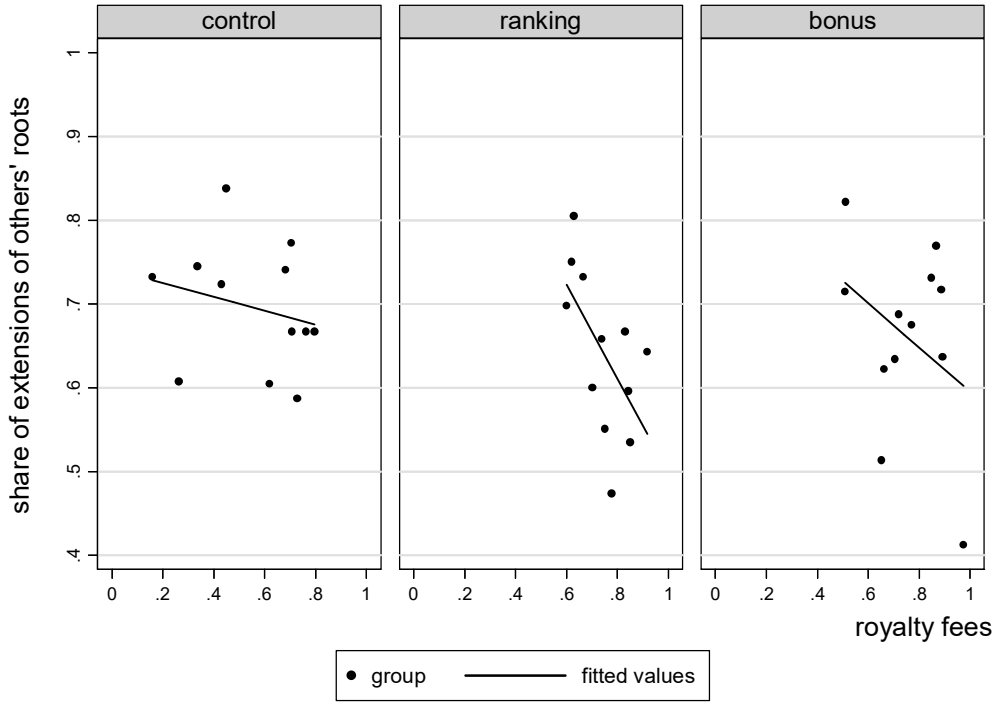
Recall that royalty payments are merely a matter of redistributing income; thus, the shift in royalty fees demanded does not necessarily reduce innovation activity or welfare. By contrast, higher royalty fees might stimulate innovation activity as produced words generate additional income when used by others. Conversely, less cooperation might lead to more basic and less sophisticated innovation activity as subjects might want to circumvent royalty fees, whereby revenues of reusing inputs (letters) are thus foregone. In the following, we investigate the relevance of these two contradicting views, which refer to Hypotheses 1b, i.e. whether the actual cooperation is lower in the contest treatments.

We can measure whether the higher royalty fees demanded in *ranking* and *bonus* transfer to a less cooperative innovation process by considering figure 2, which details the share of extensions of other subjects' roots plotted against the level of royalty fees demanded.

The figure again shows the overall higher level of royalty fees demanded in *ranking* and *bonus*. We can now answer the question of whether the unwillingness to cooperate merely increases the price of cooperation or if cooperation itself is decreasing. Although the share of others' words extensions tends to be higher for *control* with mean=.69 and sd=.07, the difference fails to be significant for *ranking* with mean=.64 and sd=.09 (MWU-test: z=-1.447, p=.1479) and *bonus* with mean=.66 and sd=.11 (z=-.636, p=.525).

[13] Unless indicated otherwise, all tests are performed at the group level, i.e. each group gives one independent observation only.

Figure 2. Share of extensions of others' roots and royalty fees by group



RESULT 2: *While the willingness to cooperate is lower for a competitive payment scheme in innovation contests (H1a), the actual cooperation as measured by the tendency to use others' prior innovations is not significantly lower (H1b).*

4.2. Innovation activity

4.2.1. Total innovation activity

Aggregate income for groups is given by the total value of the produced words minus costs for the letters bought, denominated in the following as *total net value*. An individual's income is defined as the aggregate value of the produced words minus the royalty fees paid and the costs for the letters bought.

To assess innovation activity, we distinguish between basic and more sophisticated innovations. Extensions always build upon prior roots and potentially prior extensions. As explained above, using letters several times is beneficial as the letters only have to be paid once. The ratio of extensions to roots crucially influences total innovativeness as sunk costs for the letter endowment within a group become less relevant the more extensions are created. This ratio is also reflected in the average word length and the average word value within groups. Table 2 summarizes the key figures of innovation activity by treatment.

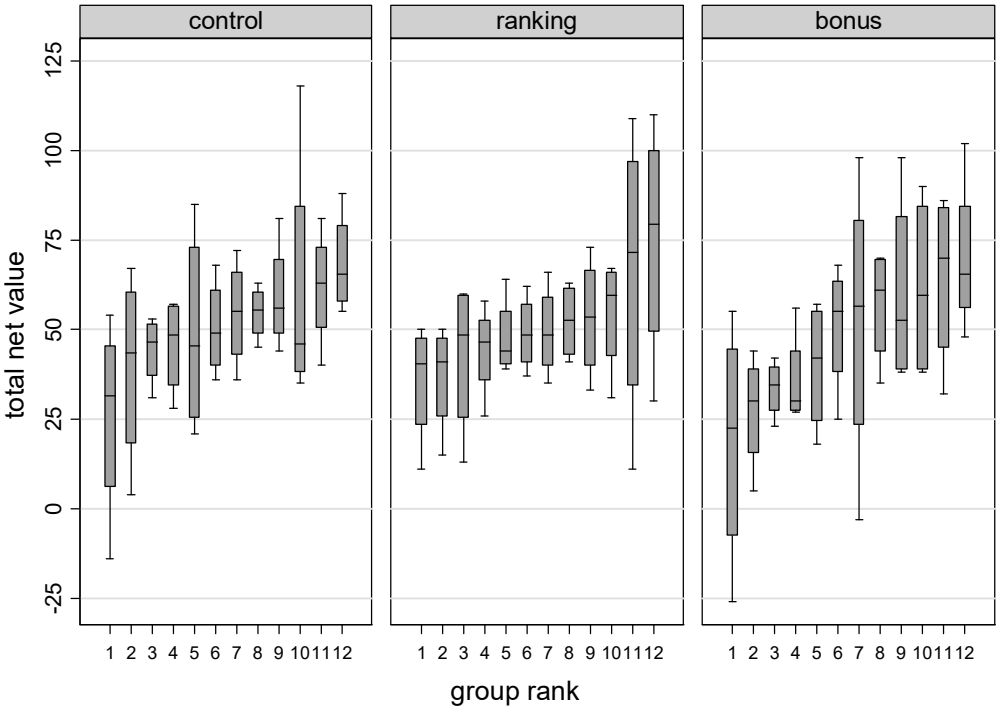
Table 2. Overview of words and value created by treatment

		control	*ranking*	*bonus*
letters bought	mean (sd)	84.3 (8.05)	82.17 (5.78)	85 (5.48)
total net value	mean (sd)	204.92 (46.23)	201.83 (44.69)	190.33 (65.32)
	median	210	197	205.5
	min	103	142	74
	max	274	299	281
word length	mean (sd)	4.49 (.32)	4.53 (.31)	4.54 (.31)
word value	mean (sd)	6.62 (0.37)	6.74 (0.49)	6.91 (0.69)
max. word value	mean (sd)	12 (2.00)	11.92 (2.07)	15.08 (3.34)
no. extensions	mean (sd)	43.33 (6.21)	41.5 (5.35)	38.58 (8.37)
no. roots	mean (sd)	13 (2.22)	12.67 (2.61)	13.33 (2.67)
extensions per root	mean (sd)	3.41 (.74)	3.46 (1.03)	3.06 (1.17)

Almost all key figures indicate similar results across treatments.[14] The maximum word value achieved is significantly higher in *bonus* when compared to *control* (MWU-test: *control* vs. *bonus* z=-2.278 and p=.0228). Figure 3 illustrates the distribution of the total net value across treatments in further detail. Again, there are no substantial differences.

[14] Applying a Mann-Whitney test at the group level does not indicate any significant differences between *control* and *bonus* or *control* and *ranking*.

Figure 3. Value of words produced within ranked groups by treatment



RESULT 3: *We find no support for H2, given that there are no significant differences in the total innovation activity regardless of the innovation contest. Nevertheless, the most sophisticated innovation is significantly more valuable when there is a prize for the best innovation.*

4.2.2. Controlling for the actual choice set

In this section, we control for the actual choice set to check the robustness of our results presented in the previous section. As the game is characterized by path dependency given by the extendibility of words produced early in the game, differences across treatments and groups might be driven by the actual choice set available. We aimed at minimizing the importance of this aspect by endowing each group with the same letter set, although each action in the game still determines the choice set for future innovations due to the game's sequentiality. Nonetheless, the sequentiality and uncertainty in terms of path dependency are essential characteristics of the innovation process and thus have to be incorporated into a well-designed innovation experiment.

We draw upon a reduced – or rather myopic – approach of rationality, given that it is not expected that subjects are able to calculate the optimal choice with respect to the whole 25 periods owing to the high complexity, uncertainty and path dependency. However, subjects

might choose optimally in terms of the opportunities in the current period. Therefore, we calculate the relative net value (RNV) (Brüggemann et al. 2014). Let C_{it} denote the actual choice set for subject *i* in a specific period *t*, determined by the available letters and the words already produced. The payoff in each period $\pi(c_{it})$ is a function of the actual choice taken $c_{it} \epsilon C_{it}$ and equals the aggregate value of the letters used minus the paid royalty fees and the cost for letters. The maximum payoff is defined as $M_{it}=max\{\pi(c_{it}),c_{it}\epsilon C_{it}\}$ and the minimum is defined as $m_{it}=\{\pi(c_{it}),c_{it}\epsilon C_{it}\}$. The relative net value RNV_{it} is subsequently given by:

$$RNV_{it}=(\pi_{it}-m_{it})/(M_{it}-m_{it})$$

Since the payoff for the actual choice is always within the boundaries of the minimum and maximum payoff, it holds that $RNV_{it} \epsilon[0,1]$, $m\leq 0$, $M\geq 0$ and $m\leq c\leq M$. Accordingly, a higher RNV is associated with higher payoffs. We can thus capture path dependency by identifying superior actions conditional upon the actual choice set. The RNV serves as a perfect linear transformation of actual payoffs.[15] In contrast to the aggregate created value, the RNV might decrease over periods, in which case subjects fail to take advantage of upcoming opportunities given by new word creations. However, the RNV increases when subjects learn to better exploit innovation opportunities. Table 3 summarizes the RNV by treatments.

Table 3. Relative Net Value across treatments. Summary statistics

	RNV			
	average (sd)	**Median**	**min**	**max**
control	.317 (.0309)	.311	.274	.378
ranking	.328 (.0366)	.329	.272	.372
bonus	.375 (.049)	.375	.294	.451

In contrast to our findings in section 4.2.1, the RNV is not equal across treatments (Kruskal-Wallis test on the group level, χ^2=10.245 with df=2; p=.006). The average RNV in *bonus* is significantly higher than in *control* (MWU-test: *control* vs. *bonus* z=-2.887 and p=.0039), while there are no significant differences between *control* and *ranking* (MWU-test: control vs.

[15] Keep in mind that the RNV is not a measure of the optimality of decisions for groups at large. This would require us to calculate each potential path and outcome for each decision. Obviously, this calculation task is unlikely to be solved by subjects, which prompted us to build our analysis upon the myopic maximization problem.

ranking z=-0.635 and p=.5254). Accordingly, subjects in *bonus* tend to perform better when controlling for path dependency.

Figure 4. Average values for the RNV's determinants over periods by treatment

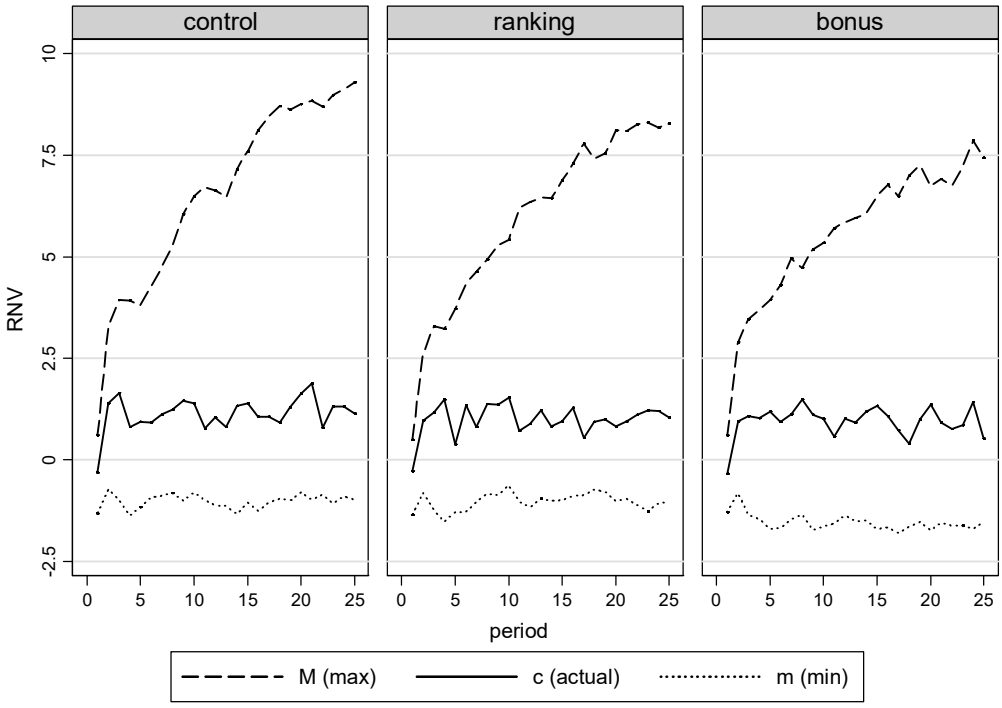
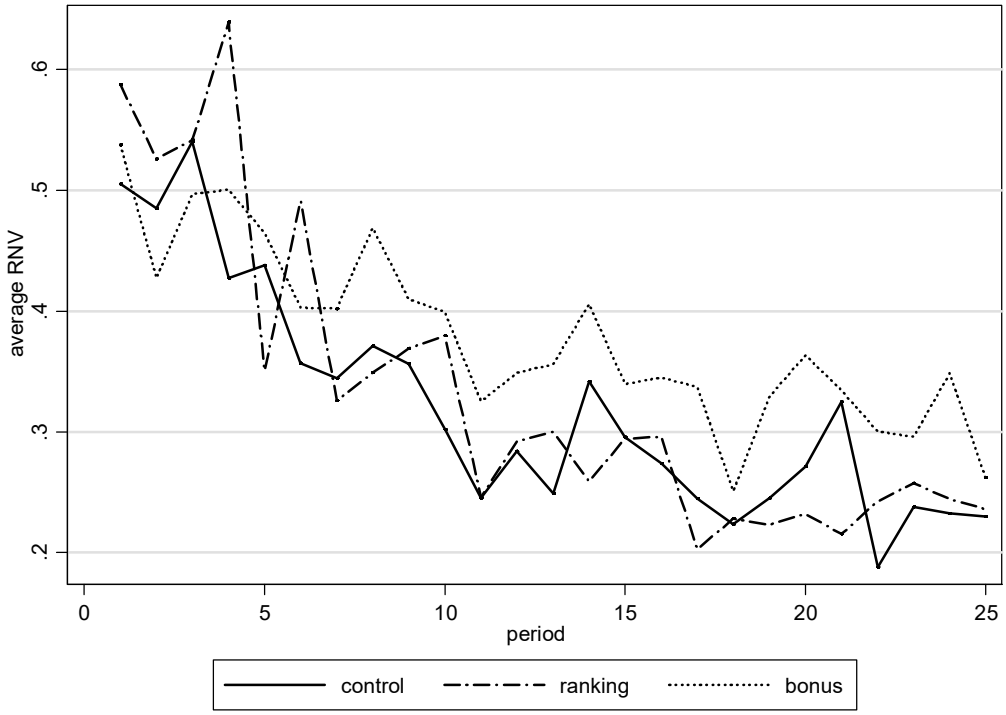


Figure 4 illustrates the dynamics of the RNV and its determinants over periods for all treatments. The graph hints at a superior creation of opportunities (M) in *control*, which can be explained by higher levels of cooperation. Nonetheless, subjects fail to keep up with the increase in opportunities, which leads to the inferior RNV values illustrated in table 3. Overall, the same pattern of subjects not being able to exploit expanding opportunities is evident for all treatments. The creation of opportunities is lower in *bonus* and *ranking*, which restricts the maximal achievable income and thus leads to a higher average RNV in *bonus*.[16] This difference becomes apparent in figure 5, which further shows that the RNV is deteriorating over time for all treatments, corresponding to the increasing number of untapped opportunities as the game proceeds. Recall that the actual payoff $\pi(c_{it})$ depends on the royalty fees that have to be paid. Therefore, the decrease in the maximal achievable income in *ranking* and *bonus* has to be explained by lower royalties demanded in *control*.

[16] Applying a Mann-Whitney test for *control* vs. *bonus* for the maximum M (minimum m) indicates a significant difference, with z=1.848 and p=.0647 (z=3.522 and p=.0004). There are no such differences between control and ranking, with z=1.213 and p=.2252 (z=.462 and p=.6442) for M (m).

Figure 5. Average RNV over periods by treatment



RESULT 4: *When controlling for the actual choice set, a prize for the best innovation substantially increases the exploitation of innovation opportunities, whereas a prize for the aggregate innovativeness does not lead to similar effects. This effect is driven by differences in the demanded royalty fees. The increase in exploitation of innovation opportunities for a prize for the aggregate innovativeness is thus not due to better performance but rather reflects the inferior creation of individual income opportunities.*

5. Concluding Remarks

The present article provides novel empirical perspective on the discussion regarding the use of innovation contests as a policy instrument to foster innovation activity. Accordingly, we transfer a sequential innovation setting to the lab by building upon a real effort word creation task. We analyze cooperation behavior and innovativeness in two types of innovation contests, namely a prize for the aggregate innovativeness and an additional prize for the best innovation. Our results show that both types of contests substantially reduce the willingness to cooperate among subjects, as demanded royalty fees significantly increase. Nevertheless, this does not reduce the actual cooperation, i.e. the propensity to make use of other innovators' products. Despite the higher royalty fees in the innovation contest treatments, the total innovativeness remains constant across treatments. This finding illustrates that subjects accept paying higher royalty fees when striving to win an innovation contest. Our results further

indicate that the intensified competition in innovation contests tends to reduce the individual income opportunities, given that higher royalty fees have to be paid.

Moreover, we derive some general policy implications. Let us consider the potential effects of innovation contests on aggregate welfare. Our results show that welfare is not necessarily increased, especially when opportunities to innovate are restricted, e.g. by the sequentiality of the process itself or constraints in the available investment capital. Furthermore, when considering the transaction costs for organizing the contest and the costs of the prize itself, overall welfare might substantially decrease. This issue is particularly relevant for state-subsidized contests, whereby taxes are reallocated while no adequate gains in innovation activity might be achieved.

Furthermore, the decreasing willingness to cooperate due to innovation contests hints at the emergence of patent races. It has been shown both experimentally and theoretically that patent races might lead to excessive spending on innovation activity and welfare losses (Loury 1979; Zizzo 2002; Silipo 2005; Judd et al. 2012). Therefore, we would suggest that the additional competitive pressure induced by prizes is likely to lead to adverse effects, particularly in domains that require broad cooperation among different individuals and groups.

It is important to note that innovation contests boost the effectiveness and importance of intellectual property rights as higher royalty fees are demanded. The willingness to cooperate decreases and an innovation system dominated by competition becomes prevalent. The simultaneous use of these policy instruments – i.e. contests and intellectual property rights – thus might have mutually amplifying negative effects, reducing aggregate welfare. Put briefly, intellectual property rights and innovation contests overlap and as intellectual property rights are established in almost every industrialized country, the implementation of state-subsidized innovation contests to foster innovation should be called into question. As suggested by Clancy and Moschini (2013), a system with a hybrid use – where innovators choose between intellectual property rights and an innovation prize – might be a solution to prevent these negative overlapping effects.

Acknowledgements: We would like to thank Kilian Bizer, Paolo Crosetto and Till Proeger for their helpful comments. Further, financial support from the German Federal Ministry of Education and Research via the Hans-Böckler-Stiftung is gratefully acknowledged.

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Appendix A

Instructions for all treatments

The differences between treatments are indicated in square brackets. The original instructions were in German and are available from the authors upon request.

The Game

In this game, your task is to build words using letters as in the board game "Scrabble". By building words, you increase your payoff: for each word, you receive a payoff calculated by the sum of the values of each letter. You start the game with an endowment of 4 letters. During the course of the game, you are able to buy additional letters.
During the course of the game, you will play in a group of 4 players.

The Payoff

[*bonus*: Your payoff results from two components: 1. **The sum of the value of your letters**]
Your payoff depends on the sum of the value of your letters, which is calculated in experimental tokens. You start the game with an endowment of 75 tokens.
[*control* and *bonus*: One token is converted to €0.12 at the end of the experiment. Note that it is possible to end the experiment with less than your starting endowment.]
[*bonus:* **€10-bonus for the "most valuable" word:** Additionally, you compete with your 3 group members: **The "most valuable" word is rewarded with a bonus of €10** at the end of the game. The player who added the last letter to the word that is valued with the most tokens receives the €10 bonus.]
[*ranking*: In this game, you compete with your three group members. Your payoff at the end of the experiment depends on the tokens you score compared to your group members: The player with the most tokens receives **€24**, while each of the other three players receives **€12**.]
[*ranking* and *bonus*: You can see how well you are performing compared to your group members at the bottom-right on the general view on the main board (see page 2).]

Please note the table below containing all letters, their value (in tokens) and the frequency with which they occur in the game. During the game, the letters are always displayed along with their value.

Table A.1: List of letters

Letter	Value	Frequency	Letter	Value	Frequency	Letter	Value	Frequency
A	1	10	J	6	2	S	1	14
B	3	4	K	4	4	T	1	12
C	4	4	L	2	6	U	1	12
D	1	8	M	3	8	V	6	2
E	1	30	N	1	18	W	3	2
F	4	4	O	2	6	X	8	2
G	2	6	P	4	2	Y	10	2
H	2	8	Q	10	2	Z	3	2
I	1	12	R	1	12			

On the next page, you will find a screenshot of the main board of the game and some explanations to gain a first overview of the game. A detailed explanation of the game ensues.

General view on the main board

All players‘ words
List of all words and information on each word: Royalty fee for an extension, the player who produced the word, value of the word.

Headings of the lists
By clicking on the column heading, the list can be rearranged.

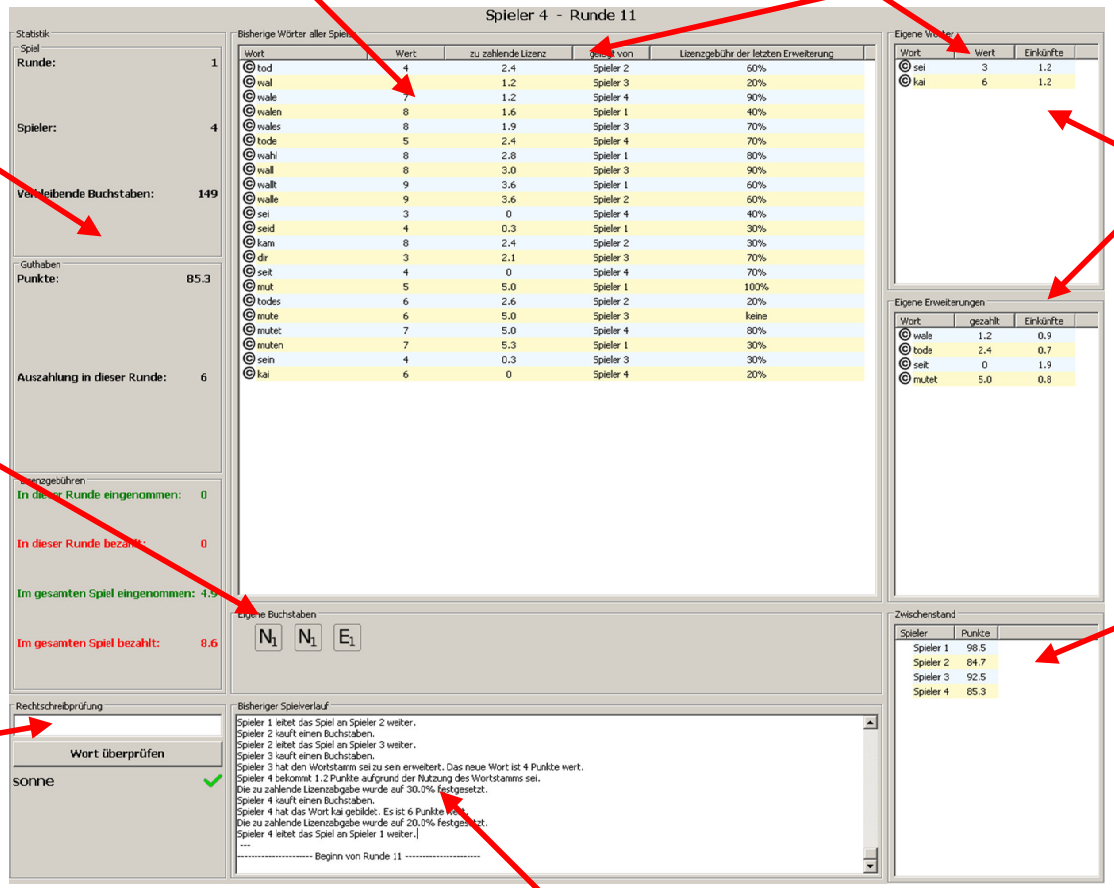
Statistics
Information on the current period, your player-ID, payoff, etc.

Your words and your extensions
You can find your own words and their royalty fees here.

Your letters
Using these letters, you can produce new words or extend words from the list above.

[*ranking:*
Score
Here you can see for each player the actual score of tokens.]
[*bonus*:
10 Euro word-bonus – preliminary result:
Here you can see your most valuable word and the ones of your group members.]

Spellchecker
You can check here, which words and extensions are allowed. Confirm your input with enter. There are no limits/ costs for usage.



Game Log
Documentation of all players‘ activities.

Course of a Turn

When it is your turn, a dialog pops up asking you for choices. During your turn, you cannot use the spellchecker. You have 45 seconds for your decisions. You can see the remaining time at the top-left corner of the screen. If your time expires, you are subtracted 1 token from your endowment for every additional 10 seconds.
Every turn comprises three phases:

1. Buying phase

Your activity: Buying letters

You can choose to buy or not to buy one letter at the price of 2 tokens. If you buy a letter, it will be chosen randomly from the list of letters shown on the table on page 1. At the beginning, you are given four letters for free. Each letter can only be used once: after producing or extending a word, the letter will be deleted from your letter set.

2. Word phase

Your activity: Producing or extending words

You can use German words, their conjugations and declinations and some names of places and persons. You can test if a word is correct using the spellchecker when it is not your turn. Correct words can be built as follows:

Option 1: Producing a 3-letter word

a) You can produce a word using exactly three of your letters.
The payoff you earn for creating a word is given by the sum of the value of the letters (Example: 'pol': p = 4, o = 2, l = 2. This results in 4+2+2 = 8 tokens).

To create a word, you have to type in the letters with your keyboard.
Please note that you cannot undo mistakes: if you make an error while inputting the word (i.e. inputting a too long, too short, non-existent or misspelled word, or pressing the enter key on an empty field), the turn passes to the next player. You will only have the opportunity to reiterate your entry correctly in the next period, during your next turn.

Option 2: Extending a word

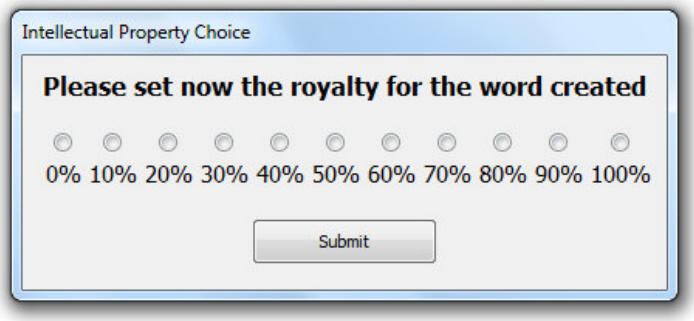
b) You can extend an existing word by inserting **one** letter in any position in the word. For example, 'ast' can be extended into '**l**ast', '**r**ast' and 'ast**e**', and 'last' again into 'la**u**st' and this into '**k**laust'. It is **not** possible to rearrange existing words (e.g. to build from 'ast' the word 'star').
Your payoff results from the sum of the value of the letters of the newly extended word. By extending e.g. 'last' into 'la**u**st', you get l = 2, a = 1, u = 1, s = 1, t = 1, so 2+1+1+1+1 = 6 tokens. Every word can only be produced once but can subsequently be used for as many extensions as possible.

Option 3:	**Passing**

c) In case you are unable to produce or extend any word, you can pass the turn to the next player.

3. Royalty phase

Your activity: Setting a royalty fee
After producing a word, you have to set a royalty fee that other players are required to pay when creating extensions. The fee must be set between 0 and 100 percent of the value of the word.



If another player extends your word, he automatically transfers the fee to you.

- 0 percent means that the word is entirely free for other players.
- At 100 percent, the next player only receives the value of his added letter.
- The choice of 20 percent means that the respective player has to pay 20 percent of the value of the word to you.

The royalty fee for a word remains fixed during the entire game. The word appears on the list of public words on the main board and can be used by everyone. However, other players have to pay the royalty fee when extending the word.
Furthermore, you will have to set a royalty fee if you extend a word with one letter. In this case, you decide on the fee only for your added letter. Your payoff results from the sum of the value of all letters minus the royalty fee for the word that you built upon.

After that, your turn ends and it is the next player's turn. The game is played for 25 periods.
Finally, some payoff-examples are offered for clarification:

Examples of Potential Payoffs:

Example 1: If player 1 sets a royalty fee of 90 percent for the word 'ast' (value of the word 3 tokens: a = 1, s = 1, t = 1) and player 2 extends the word into '**h**ast' (value of h = 2), this results in the following payoffs:
Player 1: 90 percent of 3 tokens = 2.7 tokens. (royalty fee for player 1)
Player 2: 3 – 2.7 tokens (to player 1) + 2 tokens for the letter 'h' = 0.3 tokens + 2 tokens = 2.3 tokens

Example 2: If player 1 sets the royalty fee of 0 percent for 'ast', player 2 receives the sum of the value of all letters for extending it into '**h**ast':
Player 1: 0 percent of 3 tokens = 0 token
Player 2: 100 percent of 5 tokens = 5 tokens

Example 3: After extending a word, the player has to set a royalty fee for the added letter. Player 1 sets a royalty fee of 10 percent for 'ast' and player 2 sets a royalty fee of 50 percent for the letter 'h' in '**h**ast'. If player 3 then extends 'hast' into 'ha**u**st', this results in the following payoffs:
Player 1: 10 percent of 3 tokens = 0.3 (royalty fee for player 1)
Player 2: 50 percent of 2 tokens = 1 (royalty fee for player 2)
Player 3: 6 tokens for 'haust' – 0.3 tokens (to player 1) – 1 token (to player 2) = 4.7 tokens

Appendix B

Instructions for the word task

Note: The instructions for the word task were shown on screen.

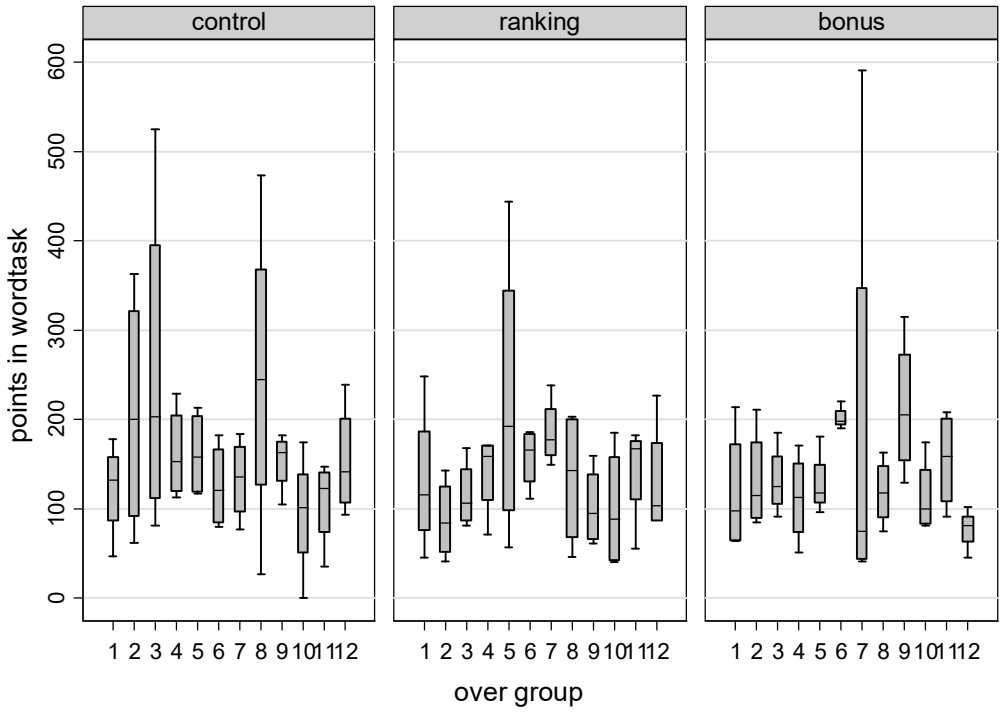
In the next screen, you will see a string comprising 9 letters.
You will be asked to create as many German words as possible using these letters within 3 minutes.
You can type the words you create in the field beneath the string of 9 letters and submit them by hitting Enter.
You can use each letter only once per word and a word cannot be shorter than 3 letters.
Longer words generate more points.
3-letter-word: 3 + 2 + 1 = 6 points
4-letter-word: 4+ 3 + 2 + 1 = 10 points
etc.
After the 3 minutes have expired, the test will end and you will be shown your results.
As soon as you enter the next screen, the timer will start ticking.
To proceed to the next screen, please press the letter 'R' on your keyboard.

Appendix C

Results of the control task

Treatment or group comparisons might heavily depend on the task-specific knowledge of some participants. As four subjects interact and potentially cooperate on only one innovation market, observations are not independent. A group's performance might be driven by a single subject showing very high or very low ability with respect to the word task. Therefore, we carried out an additional task before the experiment, which allows us to control for individual task-specific knowledge when analyzing innovation activity. We implement a task introduced by Eckartz et al. (2012): within three minutes, subjects are asked to build as many words as possible out of a 12-letter set (*accehhikllst*). Subjects accumulate points by building words, where points assigned increase disproportionally with word length. According to the aggregate points, the best three subjects of each session are paid 1€, which should guarantee that subjects put real effort into building words according to their best ability. Figure 5 shows the achieved points over groups by treatment.

Figure C.1. Control task results over group by treatment



There are no substantial differences across treatments (Kruskal-Wallis test gives χ^2=1.461 with df=2 and p=.4817), while evidently there is some heterogeneity in task-specific knowledge across groups within treatments.