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**THE EFFECTIVENESS OF PUBLIC
SUBSIDIES FOR PRIVATE
INNOVATIONS. AN EXPERIMENTAL
APPROACH**

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THE EFFECTIVENESS OF PUBLIC SUBSIDIES FOR PRIVATE INNOVATIONS. AN EXPERIMENTAL APPROACH

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Abstract:

The effects of public subsidies in supporting innovative activity is subject to long-standing debates. Since empirical findings remain largely inconclusive, this study adds to this debate with counterfactual evidence from a laboratory experiment. In a creative real effort task simulating the innovation process, two distinct means of allocating subsidies are compared to a benchmark treatment without subsidies to identify their effects in fostering innovativeness. Furthermore, subjects' cooperative behavior in relation to subsidies is investigated. Overall, subsidies lead to a substantial crowding-out of private investment. While the individual revenues increase due to the subsidy, the innovative activity fails to increase and less sophisticated innovations are realized. Consequently, subsidies have no or negative effects on overall welfare, depending on the subsidy specifics. However, subsidies do not influence cooperative behavior. These findings imply that the additional costs of subsidies for innovations might not be warranted by gains from additional innovations and increased welfare.

Keywords: creativity, innovation policy, laboratory experiment, real effort task, subsidies

JEL-Classification: C91, H25, O31

1. Introduction

Industrialized states use a broad composition of different policy instruments to stimulate innovations and thus promote the growth of their economies. This long-standing political objective has fostered broad discussions among policy-makers as well as in the scientific community about the determinants of innovation-based growth and the most effective policy mix in terms of incentivizing firms and individuals to innovate (Flanagan et al. 2011; Guerzoni and Raiteri 2015). Among the most frequently used regulatory instruments are direct monetary subsidies in the form of government grants provided to firms that develop and implement innovative products and services. Advocates of this form of governmental support claim that subsidies can help to increase the overall level of innovative activity, which would otherwise fail to reach a desirable level from a welfare perspective. Furthermore, it is argued that monetary subsidies can be distributed efficiently; for example, by implementing specific tax regulations or funding specific projects. By contrast, opponents of innovation subsidies point to a selection bias problem, criticizing that the distribution of subsidies tends to be selective and often fails to allocate funds optimally, thereby providing support for firms that are considered successful beforehand and would succeed regardless. Moreover, it is argued that the supported firms might use the grants more carelessly than their own resources, possibly resulting in dissipating or idle behavior. In addition, it is pointed out that the administration and allocation of subsidies entails considerable costs for the state and potentially leads to a crowding-out of private investment without increasing innovations and growth overall (Jaffe 2002).

The controversial debate on innovation subsidies among policy-makers is reflected in the scientific debate, which has yielded inconclusive findings on the economic effects of subsidies in fostering innovation activities (Zúñiga-Vicente et al. 2014). Aiming to craft more effective economic policies using theoretical and empirical analyses, a large number of empirical studies have examined the effect of subsidies. The results of these studies range from an additive effect on private R&D (Aerts and Schmidt 2008), no effect (González and Pazó 2008) to a crowding-out of private investment (Wallsten 2000). Furthermore, the effects of subsidies and cooperation on innovative firm behavior are emphasized, with a number of studies arguing that cooperation can positively influence innovative activities (Czarnitzki et al. 2007; Fornahl et al. 2011; Nishimura and Okamuro 2011). Blasio et al. (2014) sum up the ambiguous findings on the effectiveness of subsidies and the lack of unequivocal evidence with a basic methodological problem: “Beyond public declarations and legitimate hopes, however, there is little agreement on the effectiveness of public spending to foster private R&D. The reason is that to evaluate the effects of government-sponsored programs it is necessary to address the intrinsically difficult

counterfactual question of what would have happened without the subsidies” (Blasio et al. 2014, 26).

Building upon the statement by Blasio and colleagues, this paper aims to contribute novel empirical evidence regarding the effectiveness of innovation subsidies by creating an experimental setting that enables investigating counterfactual questions. Similar to Sørensen et al. (2010)’s suggestion, a series of laboratory experiments is conducted to analyze the effects of subsidies on the investment in and emergence of innovations. This setting is implemented to simulate the innovation process and thus compare *ceteris paribus* whether innovators receiving different forms of subsidies act systematically differently from those without external funding. While replicating the creative and dynamic innovation process within a task feasible for student subjects places certain restraints on the external validity of the results, the methodological approach has strong advantages; namely, the first counterfactual analysis of the effects of different forms of innovation subsidies can be presented, which includes the key features of innovation – i.e. risky investments, ownership and creativity – and thus completely reproduces the cumulative innovation process. To this end, a novel experimental setting is used that builds upon the board game *Scrabble*, in which subjects use letters to create words, are compensated for their innovation and are allowed to set license fees for their newly-created words (Crosetto 2010; Brüggemann et al. 2014).

In the first experiment, a benchmark treatment without subsidies is compared to a treatment in which subjects are provided with additional material resources in the form of extra letters; thus, the subsidy is limited to the use in innovative activities. In the second experiment, the benchmark is compared to a treatment providing subjects with monetary subsidies that can be used to buy additional letters. On a continuum ranging from a restrictive grant-in-aid to a freely-usable financial assistance, this experiment implements two distinct variants that tend towards either end of the continuum. In both settings, license fees can be imposed on innovations, which provide a measure of cooperative behavior among participants. The experiments thus only differ with respect to the form of the subsidies. In both benchmark treatments, subjects are required to buy their letters: in the first experiment, subjects receive a free letter each period; while in the second experiment, they receive an additional payoff worth one letter in each period. With this experimental design, the effect of the two different forms of subsidies on individual investment and cooperation behavior can be tested to assess which more effectively increases innovativeness.

The results indicate that subsidies have no positive effects on individual innovativeness and overall welfare. Providing additional material resources restricted to the use in innovations yield no differences in welfare; indeed, offering freely-usable additional monetary resources even

leads to a loss in overall welfare. Although innovators' individual incomes increase due to the subsidies, no increase in the innovative activity results; rather, subsidies substantially crowd out private investment. Regarding the specifics of innovations, subsidies foster the realization of less sophisticated innovations. In turn, cooperative behavior – as measured by the level of license fees chosen – is not affected by subsidies. From a policy perspective, the results indicate that subsidies may not yield positive effects in terms of innovativeness and overall welfare and they could even induce negative overall welfare effects when accounting for their additional costs to the state.

The remainder of this paper is structured as follows. Section two presents a review of the literature on subsidies and innovation, before section three explains in detail the experimental design and section four describes the behavioral hypotheses. The experimental results are provided in section five and section six provides policy implications and finally concludes.

2. Literature Review

There is a large body of empirical literature discussing the effectiveness of public subsidies by examining different government programs.¹ In a literature review, David et al. (2000) report that no crowding-out of private innovation investments through public subsidies occurs in two-thirds of the studies, whereby the crowding-out effect seems stronger in the USA compared with Europe. Therefore, in the majority of the studies reviewed, public subsidies are shown to have a positive impact on the innovative activity. Overall, Klette et al. (2000) also find positive results when comparing five empirical studies in detail, yet they also point to methodological problems inherent in the studies. By contrast, in a more recent review, Zúñiga-Vicente et al. (2014) sum up the literature by stating that the effectiveness of public subsidies has to be called into question due to the improved data quality in recent years. From a financial market perspective, Hall and Lerner (2010) survey the discussion of a “funding gap” in the investment for innovations and emphasize that further research should be conducted, ideally in an experimental or quasi-experimental setting.²

Overall, the empirical evidence for developed countries is inconclusive, with many studies pointing to a positive impact on private innovative activity (Czarnitzki and Hussinger; Almus and Czarnitzki 2003; Aerts and Schmidt 2008; Hussinger 2008; Aschhoff 2009; Aschhoff and Sofka 2009; Duch et al. 2009; Czarnitzki and Lopes Bento 2012; Czarnitzki and Lopes-Bento 2014). Similarly, a number of studies also identify mixed effects on the innovative activity (Cerulli and Potì; Busom 2000; Heijts and Herrera 2004; González et al. 2005; Görg and Strobl

¹ For an generalist overview of innovation research see Hong et al. (2012).

² For the specific effects of tax incentives see Hall and van Reenen (2000).

2007; Clausen 2009; Fantino and Cannone 2013; Bronzini and Iachini 2014; Becker 2015). Conversely, other studies do not support these results and find no positive effects of public support on innovative activity (Lach 2002; Hujer and Radić 2005; González and Pazó 2008; Norrman and Bager-Sjögren 2010; Blasio et al. 2014). Furthermore, a few authors show a full or partial crowding-out of private investment as an unintended negative effect of subsidies (Goolsbee 1998; Wallsten 2000).

Moreover, many studies on the determinants of innovativeness find a positive impact of cooperation on the innovation output (Branstetter and Sakakibara 2002; Becker and Dietz 2004; Aschhoff and Schmidt 2008; Faria et al. 2010; Schwartz et al. 2012). Discussing the effects of cooperation on subsidized innovative activity, Czarnitzki et al. (2007) assume that the innovative output of collaborating by non-subsidized firms would increase when participating in grant-in-aid programs. Nishimura and Okamuro (2011) show positive effects of subsidies on joint innovative activity after subsidy programs have ended, with their results indicating that indirect support programs have a strong impact on the innovative activity. For firms cooperating in research activities, Fornahl et al. (2011) show that state subsidies increase the innovative activity, as measured by patent applications. However, this finding does not hold for single firms. Falck et al. (2010) find positive effects on the innovative activity of firms that pursue a cluster-oriented policy, yet a decrease in private innovation expenditure. Furthermore, Sakakibara (2001) shows that subsidies have a slightly negative effect on cooperating firms' investment in innovation.

From a methodological perspective, Blasio et al. (2014) and Cerulli (2010) provide an overview of the existing empirical methods to analyze the effects of subsidies on innovativeness and discuss the problems concerned with analyzing the data in this particular field. They state that the impact of innovation subsidies cannot be effectively separated from unrelated effects and they declare that counterfactual evidence is required for more definite empirical evidence. Therefore, Sørensen et al. (2010) suggest that experimental methods should be introduced to innovation research. To date, a small number of experimental studies have dealt with topics of innovation and analyzing different innovation policy instruments. Eckartz et al. (2012) test the effects of different incentive schemes and find no substantial differences between payment schemes. Cantner et al. (2009) simulate a patent race by means of a multidimensional search task with uncertainty, finding that the difference in the subjects' earnings has a positive impact on their investment in the next periods. Darai et al. (2010) investigate the effects of increased competition on investments in process innovations. Implementing both a one- and two-stage setting, they find that competition through additional firms reduces investments, whereas – contrary to theoretical predictions – switching from Cournot to Bertrand competition increases

investments. Aghion et al. (2014) implement a scenario of competition in a sequential innovative setting. They use a risky investment task and test for the effects of different levels of competition and time horizons. Overall, they find that competition leads to an increase in investment for neck-and-neck firms and reduced investments by firms lagging behind. Busso and Galiani (2014) present a field experiment in the Dominican Republic to determine the influence of competition on prices and quality. They find that the intervention that led to increased competition fostered a decrease in prices yet no changes in product and service quality. Ederer and Manso (2013) analyze different payment schemes for innovators by implementing a search task and observe that the possibility of early failure and rewarding long-term success motivates innovators more than pay-for-performance or a fixed wage. Focusing on the policy instrument of intellectual property rights, Buchanan and Wilson (2014) also conduct a search task to simulate innovative activity, providing evidence that innovative activity is fostered by intellectual property rights yet simultaneously induces higher prices for innovations. Meloso et al. (2009) use the knapsack problem as a search task, in which participants have to combine items of a specific value and weight in the optimal combination to simulate the innovation process. They show that innovativeness is higher in a free market-based system compared with a patent-based system.

Extending these studies to more accurately simulate the crucial features of innovation processes in the laboratory, recent experiments have introduced elements of investment, ownership and creativity in their tasks. Crosetto (2010) first implemented a real effort word creation task to test for innovation behavior, providing subjects the possibility to choose the preferred regulatory incentive scheme, namely open source or fixed license fees. Based upon the board game *Scrabble*, the innovation process is simulated by having subjects create and extend words. Following this approach, Brüggemann et al. (2016) extend the design by implementing endogenous license fees and thus showing an increase in welfare without intellectual property rights. Considering different institutional mechanisms for fostering innovation, Brüggemann and Meub (2015) use the same experimental approach, showing that innovation contests reduce the willingness to cooperate between innovators and do not lead to additional gains in innovative activity and welfare. Further building upon the experimental design introduced by Crosetto (2010), a real effort word creation task is implemented to test the effectiveness of subsidies as a policy instrument. Hence, two experiments are run to investigate the effect of two different forms innovation subsidies, namely providing resources exclusively determined for use in innovations and providing additional financial resources unrestricted to a specific application.

3. Experimental Design

3.1. Design

General properties of the game

To determine the effect of subsidies on the individual innovation behavior in a sequential setting, a real effort word creation task inspired by the board game *Scrabble* is implemented. During the experiment, subjects have to act both strategically and creatively, facing the investment decision of buying letters and acting creatively by building words, thus generating their payoff. Additionally, subjects are able to set a license fee for their newly-created words, which can be extended by other players in the course of the game. The experiment closely builds upon the experimental design introduced by Crosetto (2010) and has been modified by Brüggemann et al. (2014) and Brüggemann and Meub (2015).

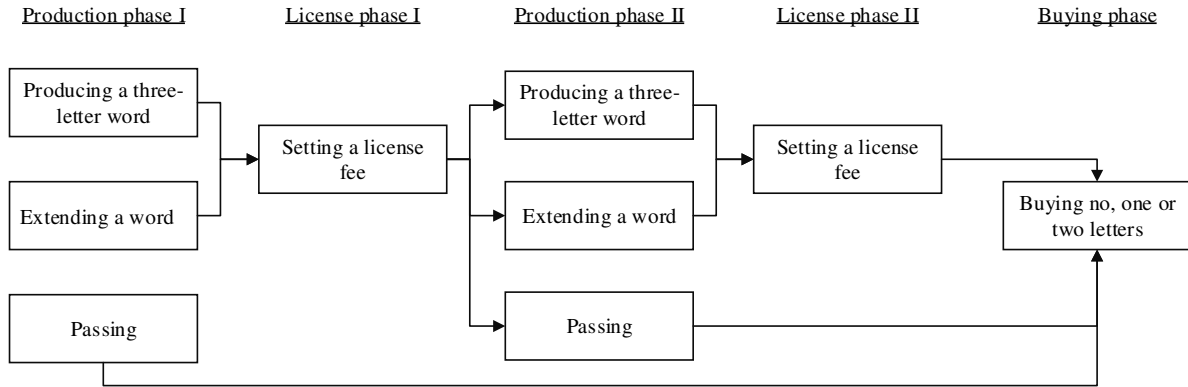
This basic setting is extended using a within-subject design, whereby each subject plays 12 periods of the real effort word creation task twice, once in the control group and once in the treatment group. The order of control and treatment groups is reversed for half of the subjects to control for distortions due to the sequence of treatments. The game is played in groups of four players, who are randomly matched for the first part over 12 periods. Once all subjects have finished the first part, subjects are again randomly matched for the second part of the game, similarly comprising 12 periods. In both parts of the game, each subject is endowed with 50 tokens and four randomly pre-selected letters.³

³ Before the main task starts, subjects had to complete a short control task, in which their word-finding skills were tested. The instructions for the control task can be found in appendix B, the results in appendix C.

Course of a turn

In each period and treatment, subjects run through five phases, for which figure 1 provides an overview.

Figure 1. Overview of a subject's turn



In the production phase, subjects are asked to choose between producing a three-letter word (*root*), extending an already existing word (*extension*) or passing the turn. If subjects create or extend a word, they are asked whether or not they wish to set a license fee in the ensuing license phase. The production and license phases are played twice in each turn. In the last phase of each turn – the investment phase – subjects can buy up to two new letters.

Creating a word

A *root* must comprise exactly three letters and it yields a payoff equal to the sum of the values of the letters used. Each word can be extended several times with exactly one letter in each production phase at every position of the original word, although every word can only be produced once in the game. A newly-created or extended word is only accepted if it exists in the standard MS Windows dictionary for German. A letter has the same value as in the German version of the board game *Scrabble*, which is determined inversely proportional to its frequency in the German language; for example, the letter *e* has the value 1 and the letter *x* the value 8. The payoff for each word is calculated by the sum of all letters of the word. This also applies if a player adds a letter without having produced the original word. Thus, adding a letter to an existing word generally yields a higher payoff than producing a root. Consider for example⁴: given the letters *a*, *e*, *r* and *t*, a subject can create the roots *art*, *ear* or *rat*. If the respective letters are available, *art* can be extended into *arts* and *dart* or *part* – and *part* again into *apart* or *party*.

⁴ The game was run in German. However, word examples and instructions are provided in an English translation in appendix A and B.

The root *art* has a value of $1+1+1=3$ tokens, whereas the extension *apart* has a value of $1+3+1+1+1=7$ tokens.

This basic setting enables us to model innovations in which each step of the innovative process has more or less the same value to the final product. Consequently, no statements regarding technological milestones can be derived, in which a single part of the innovative process can be interpreted as a multiplicative technological innovation. Obviously, this is a substantial limit inherent in the design choice, which reduces the scope of the applicability to real-world innovative processes. Nevertheless, while this limitation is inherent to the basic experimental Scrabble framework, it can be suggested that it continues to apply to a large number of scenarios involving sequential innovative processes characterized by incremental innovations.

Setting license fees and buying letters

Subjects are required to choose whether they wish to set a license fee or not. If subjects decide to set a license fee for their root, they are required to choose values between 10% and 100% of the word value in 10% steps. The license fee subsequently remains fixed up to the end of the 12 periods. After extending a word, subjects only set the license fee for the newly-added letter, as the license fee for the other letters is already defined by the previous producers. The new word – along with its license fee, the value and the producer – is displayed in the public word list on the game's main screen. By setting license fees, subjects receive additional income whenever another person extends a word with a license fee. However, license fees cannot be used as a mechanism to exclude other subjects from using a word altogether; rather, higher license fees merely make it less profitable for other players to use the word for an extension. Thus, license fees can be interpreted as a measure for cooperative behavior, whereby higher license fees indicate a low willingness to cooperate, i.e. making the access to one's words expensive. Lower fees show a higher willingness to cooperate by making extensions more profitable for other players. Furthermore, there are no transaction costs for the license fees, meaning that they can be interpreted as an instrument of redistribution within groups.

To illustrate this mechanism, consider again the example given above: the root *art* is worth 3 tokens and subject A sets a license fee of 60%. Subsequently, every subject who extends *art* automatically pays 1.8 tokens to subject A. Afterwards, subject B adds the letter *p* – worth 3 tokens – and extends *art* into *part*. Due to this action, 1.8 tokens are transferred to subject A and subject B earns 1.2 tokens for *art* plus 3 tokens for the letter *p*, which yields 4.2 tokens for subject B. Furthermore, subject B also has to set a license fee for the *p* in the word *part*, e.g. 50%. Subsequently, subject C creates the word *apart* and pays 1.8 tokens to subject A, 1.5 tokens to subject B and earns 3.7 tokens.

At the end of each turn, in the investment phase, subjects are asked to buy no, one or two letters for a price of 4 tokens each.

Being not at turn

Subjects can monitor the main board of the game when it is not their turn. Accordingly, they can see their letters, current earnings, follow the actions of the other subjects and see the list of all words produced. Furthermore, they can prepare their next turn by checking words and extensions with a free interactive spellchecker. This is necessary as new words are only accepted if they are implemented in the MS Windows dictionary.

Welfare considerations

Altogether, the welfare created in the game depends on the relative number of extensions, given that the expected value of a letter is negative: buying a letter costs 4 tokens, yet the average value of a letter is 1.87. Therefore, buying a letter is a risky investment for a potential innovator, as it might lead to negative returns. Consequently, if a group only produced roots, it would experience a decline in welfare as their initial endowment would continually decrease during the game. Only by creating extensions can letters be utilized several times and thus increase overall welfare. Thus, from a welfare perspective, a group optimally creates a rather small number of roots in the beginning and subsequently refrains from creating new ones, but rather uses letters exclusively to extend existing words. Once a number of roots has been created, it becomes – in most cases – unfavorable to the overall and individual incomes to create additional roots, giving players a clear rational strategy in terms of income maximization. Obviously, this strategy only holds given that a number of players bore the individual costs of putting down roots in the initial periods of the game.

3.2. Treatment conditions and experimental procedure

Two experiments were implemented to test for two potential designs of subsidies. They only differ compared with the control treatment in terms of the allocation of resources, as shown in table 1. In a within-subject design, both treatments are tested against *control*, where subjects do not receive a subsidy and are allowed to buy up to two letters at the end of their respective turn. In the first experiment (*ExLetter*) in *subsidy*, subjects receive an additional letter for free at the end of their respective turn and are allowed to buy one more letter. In the second experiment (*ExMoney*), in *subsidy*, subjects receive four additional tokens at the end of their turns, which is equivalent to the cost of one letter. As in *control*, they are allowed to buy up to two more letters at the end of their respective turn. In both *ExLetter* and *ExMoney*, subjects are informed

in each turn that they receive the additional resource or the additional money, respectively. The order of the treatments is reversed in half of the sessions to compensate for learning and other effects related to the order of treatments.

Table 1. Overview of the treatment conditions

	<i>ExLetter</i>		<i>ExMoney</i>	
first part	<i>control</i>	<i>subsidy</i>	<i>control</i>	<i>subsidy</i>
second part	<i>subsidy</i>	<i>control</i>	<i>subsidy</i>	<i>control</i>
no. of participants	36	36	40	36

The 191 letters used in the game were distributed in a fixed yet random order to make the actions of the groups better comparable. Therefore, the order in which the letters were allocated to the subjects was randomly predetermined for each game before the experiment. Half of the subjects in each experiment first received the letterset from Brüggemann et al. (2014) in the first part of the game and a newly-created letterset in the second part, which was similarly randomly predetermined. For the other half of the subjects, the order in which the lettersets were used was reversed. This reversal of lettersets was again used to compensate for effects connected to the order of the letters.

The experiments were conducted in the Laboratory for Behavioral Economics at the University of Göttingen with a sample of 148 subjects from different academic disciplines. The software used for running the experiments was programmed using Python (Crosetto, 2010). Participants were recruited using ORSEE (Greiner 2004), whereby each subject was allowed to participate in one session only and none had previously participated in a similar experiment. The experiments took place in April 2014 and each session lasted around 90 minutes. On average, participants were 24.9 years old, 48.0% were female and 39.2% were students of economics. Each participant earned €16.99 on average, with a minimum payoff of €8.3 and a maximum of €30.2.

4. Hypotheses

With this experimental design, novel insight is provided for the counterfactual question concerning what effects result with and without subsidies *ceteris paribus*. The design provides insights concerning how subsidies influence the individual behavior of innovators and thus it complements discussions on innovation subsidies (Zúñiga-Vicente et al. 2014).

First, the potential effects of subsidies on the cooperative behavior of subjects can be addressed. The initial hypothesis is motivated by previous empirical studies on the effects of subsidies on

cooperation. Nishimura and Okamuro (2011) find a positive impact of subsidies on innovative activities pursued in inter-firm cooperations, thus increasing the innovative output of participating firms. Consequently, the output of firms working in innovation networks is often higher compared to that of firms innovating independently (Falck et al. 2010; Fornahl et al. 2011; Nishimura and Okamuro 2011). To provide behavioral evidence on individual decision-making in these situations, the individual choices of license fees can be used in this setting. On a behavioral level, more cooperative behavior in terms of lower license fees cannot unambiguously be qualified as the benchmark for rational decision-making. However, for a profit-maximizing player trying to open up as many potential innovative paths as possible, lower license fees should be used as a signal to other players to similarly keep license fees low and thus encourage common word creations. Additional resource allocations in the form of subsidies do not change this optimal behavior, as players should attempt to keep license fees low to encourage additional innovative paths in both cases. Therefore, hypothesis 1 is formulated:

Hypothesis 1 (“Cooperative behavior”)

Cooperative behavior is similar for *subsidy* and *control*.

Second, the investment behavior can be investigated when analyzing the letters acquired and the individual revenue for the innovators. This particular domain can be motivated by the majority of empirical studies, arguing that public support does not lead to a crowding-out of private investment in most cases (David et al. 2000). However, some more recent studies question this assumption (Blasio et al. 2014; Zúñiga-Vicente et al. 2014). This experimental setting can contribute individual behavioral evidence to this open question.

Recall that a letter in this setting costs 4 tokens, while the average return of a letter is 1.87, which makes buying an additional letter a risky investment. Hence, subjects rationally restrain their investments and refrain from buying as many resources as possible. In this situation, additional resources lead to either increased innovativeness – as intended by regulators – or a crowding-out of private investments and an unchanged number of innovations. Assuming that players are motivated to maximize their payoffs from the game, it would be the rational choice to add the subsidies to their private investment and thus increase their chance of producing more valuable innovations. Thus, given payoff-maximizing players, there should be no crowding-out of private investment and individual revenues should increase. Therefore, hypothesis two is formulated as follows:

Hypothesis 2 (“Investment & revenue”)

- a) There is an increase of private investment in *subsidy* in both experiments when compared to *control*.
- b) Crowding-out of private investment does not occur in *subsidy* when compared to *control*.
- c) The individual revenue is higher in *subsidy* in both experiments when compared to *control*.

The third hypothesis is motivated by recently increasing doubts regarding the positive effects of subsidizing private innovative activities (Zúñiga-Vicente et al. 2014), a substantial number of studies emphasize that innovation subsidies have positive effects on a country’s overall innovative capacities and thus economic welfare (Czarnitzki and Hussinger; David et al. 2000; Czarnitzki and Lopes-Bento 2014). This paper again contributes individual behavioral patterns to this discussion by testing the overall welfare effects of innovation subsidies in an economic experiment.

It can be assumed that rational players aim at maximizing their payoffs by using their newly-allocated subsidies for the purpose of investing in the acquisition of additional letters and thus creating as many new words as possible. Consequently, the basic expectation is that subsidies will induce additional innovations and thus increase the overall welfare generated, as measured by the aggregated value of all words. Therefore, the following hypothesis is derived:

Hypothesis 3 (“Welfare”)

- a) The aggregated innovative activity is higher in *subsidy* in both experiments when compared to *control*.
- b) The welfare is higher in *subsidy* in both experiments when compared to *control*.

5. Results

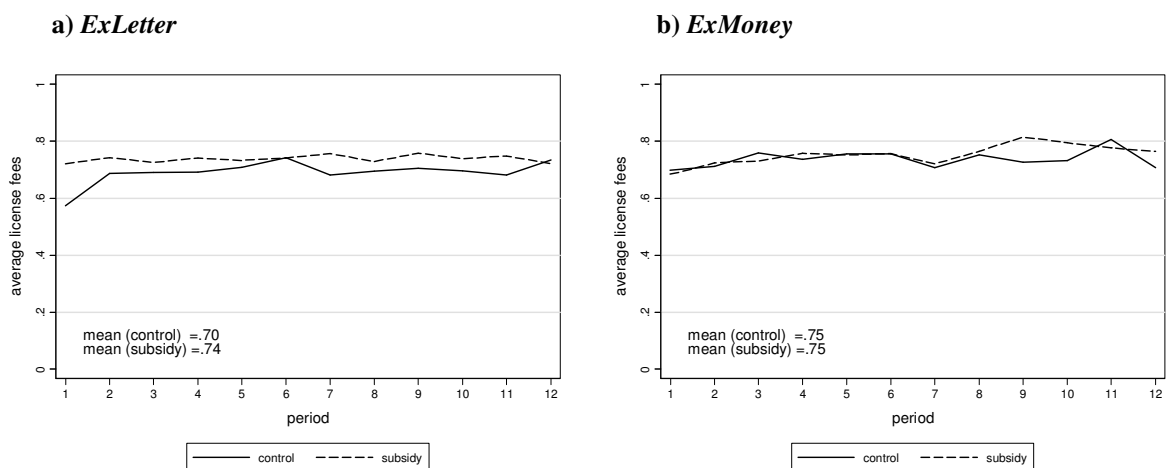
To answer the research questions as formulated in the hypotheses presented above, the results are structured as follows. First, the cooperation behavior is investigated, before the results on the individual level of the game are described, namely subjects' investment and revenue. Subsequently, the innovative activity is analyzed before the welfare perspective is taken into account and different measures of welfare are discussed.

5.1. Cooperation behavior

After having created a word, subjects were asked whether they would like to choose a license fee or not. If subjects wanted to set a license fee, they could chose between 10 and 100%. As discussed above, the license fees chosen can be interpreted as a measure for cooperative behavior (H1), whereby the higher the license fees, the less subjects are willing to let other subjects benefit from extending their produced words.

To analyze cooperative behavior, the number of words without license fees can be considered as an initial measure. In *ExLetter*, in *control*, 3.31% of all words did not have a license fee; in *subsidy* 2.10%; in *ExMoney* subjects did not select to set a license fee in *control* for 3.29% and in *subsidy* for 2.92% of all produced words. This low measures show a strong demand for being rewarded for the created innovations. The major factor is the average license fees over periods for each experiment, as presented in figure 2.

Figure 2. Average license fees over periods by treatment and experiment



The level of license fees and thus the cooperative behavior remains fairly constant over time, given that there are no differences across treatments (Wilcoxon signed-rank (WSR) test for

ExLetter $z=-0.631$, $p=.5277$; for *ExMoney* $z=.161$, $p=.8721$).⁵ There are no learning or last-round effects that occur due to the within-subject design, as assessed by testing whether there are differences due to the order of treatments. The difference in the level of license fees is calculated between the order (1) *control* and *subsidy* and the alternative treatment order (2) *subsidy* and *control*. There are no significant differences when comparing the differences with respect to the order for the level of license fees (Mann-Whitney-U (MWU) test for *ExLetter* $z=-1.634$, $p=.1023$, for *ExMoney* $z=-1.470$, $p=.1416$). Overall, subsidies do not have a detrimental influence on the cooperation behavior in this setting.

RESULT 1: *There is evidence in favor of H1 as cooperative behavior remains stable over time and across treatments.*

5.2. Investment and individual revenue

To gain an overview of individual behavior in the experiments, the revenue and the investment behavior are discussed, whereby revenue is represented by the cumulative income with and without the subsidy and investment by the letters acquired during the game. Recall that in *control* and *subsidy* of *ExMoney*, a group as a whole can buy up to 88 letters, while in *ExLetter* in *subsidy*, 44 letters are received for free and 44 letters can be bought by the subjects. The letters stock denotes a subject's average number of unused letters over the course of each treatment. The subsidy is interpreted as the resources transferred to each subject by the state. In *ExLetter*, the subsidy amounts to the value of four tokens for each letter received for free. In *ExMoney*, the subsidy equals the amount of the four free tokens, which add up to 44 additional tokens over 11 periods (excluding the final period, where no subsidy is provided).⁶ All these main indicators are reported in table 2.

⁵ In the following, all tests reported are performed at the group level, meaning that each group of four players is treated as one independent observation. If other levels of aggregation are chosen, this is separately reported.

⁶ Recall that players are provided the additional letter after the production phase, whereby additional letters could not be used in the final period and thus no additional letters are assigned. To keep the treatments symmetric, the same procedure is applied in *ExMoney*.

Table 2. Overview of investment and revenue by treatment and player

		<i>ExLetter</i>		<i>ExMoney</i>	
		<i>control</i>	<i>subsidy</i>	<i>control</i>	<i>subsidy</i>
letters acquired	mean (sd)	60.78 (10.13)	70.83 (7.69)	59.79 (8.49)	66.74 (11.15)
letters stock	mean (sd)	3.89 (.75)	4.02 (.99)	3.84 (.71)	4.21 (1.01)
income [tokens]	mean (sd)	66.47 (15.17)	101.96 (19.55)	64.03 (13.27)	100.28 (13.00)
income excluding subsidy [tokens]	mean (sd)	66.47 (15.17)	57.96 (19.55)	64.03 (13.27)	56.28 (13.00)

Note: For letters acquired in *ExLetter* in *subsidy* the amount of 44 tokens for letters received for free is added.

The table shows that introducing a subsidy increases the number of letters acquired in both experiments.⁷ However, not the entire amount provided is invested in additional letters. Subjects buy more letters in *subsidy* in *ExLetter* (WSR-test $z=-3.006$, $p=.0026$), albeit only when including the 44 letters received for free in *subsidy*. In *ExMoney*, there are no significant differences in the investment behavior between treatments (WSR-test $z=-1.269$, $p=.2043$), thus yielding the interpretation that a substantial crowding-out of private investment occurs. In *ExMoney*, this is obvious as there are no differences in the investment behavior by introducing a subsidy. For *ExLetter*, consider that each subject receives letters worth 44 tokens but only invests 70.83 tokens. Compared to the 60.78 tokens in *control*, less than a quarter of the subsidy is reinvested in additional letters. Respectively, the value of unused resources – i.e. the letters stock – increases, albeit insignificantly in *subsidy* in both experiments (WSR-test for *ExLetter* $z=-0.109$, $p=.9133$; for *ExMoney* $z=-0.885$, $p=.3760$), meaning that only slightly more resources are left unused in *subsidy* in both experiments.

Unsurprisingly, subjects overall generate more income in *subsidy* in both experiments (WSR-test for *ExLetter* $z=-3.593$, $p=.0003$; for *ExMoney* $z=-3.823$, $p=.0001$). However, considering the subsidy of 44 tokens – which almost doubles the starting endowment of 50 tokens – and subtracting the subsidy from the revenues, subjects earn less in *subsidy* in *ExMoney* (WSR-test $z=1.912$, $p=.0559$), while the difference marginally fails to be significant in *ExLetter* (WSR-test $z=1.350$, $p=.1769$).

⁷ Following the procedure outlined in chapter 5.1, the different orders of the treatments do not influence the number of letters acquired: MWU-test for *ExLetter* $z=.972$, $p=.3309$, for *ExMoney* $z=1.436$, $p=.1509$; further, they do not influence income and income excluding subsidy: MWU-test for *ExLetter* $z=-1.192$, $p=.2332$, for *ExMoney* $z=-0.735$, $p=.4624$. The sequence order only makes a difference for letters stock: MWU-test for *ExLetter* $z=2.075$, $p=.0380$ and for *ExMoney* $z=2.613$, $p=.0090$. Subjects have more letters in stock in the treatment they played first, regardless of the treatment. Consequently, since aggregated values are analyzed, the further analysis is not affected.

This result shows that the effectiveness of subsidies in this sequential innovation setting is limited. The tendency to invest increases in *ExLetter* once a subsidy is provided, although the additional investments do not account for the full amount of the subsidy. For *ExMoney*, there is no difference in the investment behavior. Thus, subsidies do not add proportionally to the investments but rather lead to a crowding-out of private investment. Considering the income excluding the subsidy yields a measure for the revenue of innovative activity at the aggregate level including the costs for implementing subsidies borne for instance by the state. Looking at this particular measure shows that the average income generated by subjects is higher when no subsidies are provided. Thus, the subsidies have primarily lead to higher incomes individually while failing to induce additional investments, innovations and the resulting revenue at the aggregate level. Thus, while individual innovativeness might be higher in both treatments, the resulting income does not compensate the costs of the subsidies. This finding raises the question of whether the additional resources spent by the state through the subsidies are used in an effective way to incentivize individuals conducting more valuable innovations. This question will be investigated in the next section by analyzing the aggregate welfare created through innovations.

RESULT 2: *H2a can partly be rejected as private investment does not increase in ExMoney. Furthermore, introducing a subsidy leads to a crowding-out of private investment, meaning that H2b can be rejected. H2c is partly rejected since introducing a subsidy increases the individual revenues, yet fails to increase aggregate revenues from innovative activities.*

5.3. Welfare and innovation

5.3.1. Innovative activity

In this section, the innovative activity is examined and different measures are developed to analyze the welfare effects (H3). Recall that as letters have to be bought at the price of 4 letters with an average letter value of 1.87, only the repeated use of letters generates welfare. Therefore, the ratio of extensions to roots is an important indicator for the innovative activity of groups. This ratio is shown in table 3, which also displays the average word length and the average word value.

Table 3. Overview of words created by treatment

		<i>ExLetter</i>		<i>ExMoney</i>	
		<i>control</i>	<i>subsidy</i>	<i>control</i>	<i>subsidy</i>
word length	mean (sd)	4.68 (.42)	4.43 (.46)	4.49 (.30)	4.42 (.28)
word value	mean (sd)	6.78 (.95)	6.54 (.92)	6.57 (.66)	6.54 (.50)
no. of extensions	mean (sd)	35.89 (7.01)	35.33 (8.67)	35.16 (7.46)	33.26 (6.66)
no. of roots	mean (sd)	9.44 (2.59)	12.5 (2.87)	9.68 (2.72)	11.84 (2.544)
extensions per root	mean (sd)	4.17 (1.82)	3.05 (1.22)	4.03 (1.69)	2.96 (1.03)

In general, the sum of the number of roots and extensions can be interpreted as a measure for the innovative activity, as they show how many innovations have been created overall. The table shows that the number of roots is higher in *subsidy* in both experiments (WSR-test for *ExLetter* $z=-2.665$, $p=.0077$; for *ExMoney* $z=-2.110$, $p=.0349$), i.e. the tendency to create basic innovations is higher when a subsidy is provided. Since extensions have a higher expected value than roots, they are more desirable from a welfare perspective. Comparing the number of extensions, there are no differences between *control* and *subsidy* in *ExLetter* (WSR-test $z=.240$, $p=.8103$) and only weak differences in *ExMoney* (WSR-test $z=1.735$, $p=.0827$). However, the number of extensions per root is higher in *control* (WSR-test for *ExLetter* $z=1.938$, $p=.0526$; for *ExMoney* $z=2.093$, $p=.0364$) in both experiments, which results from the higher total number of roots created in *subsidy* in both experiments. All other indicators show no differences between treatments and experiments.⁸

This yields the interpretation that although subjects have a higher endowment in *subsidy*, the innovative activity does not increase. By contrast, as subjects tend to create more roots in *subsidy*, they seem to use the additional resources for additional basic innovations rather than more sophisticated sequential innovations. This shift towards more basic innovations is not desirable from a welfare perspective.

⁸ Again, the results are not influenced by the sequence in which the treatments were conducted. This is tested using the procedure described in chapter 5.1: MWU-test for word length in *ExLetter* $z=-0.751$, $p=.4529$, in *ExMoney* $z=-0.245$, $p=.8065$; MWU-test for word value in *ExLetter* $z=-1.457$, $p=.1451$, in *ExMoney* $z=1.225$, $p=.2207$; MWU-test for number of roots in *ExLetter* $z=.310$, $p=.7563$, in *ExMoney* $z=.659$, $p=.5101$; MWU-test for number of extensions in *ExLetter* $z=.177$, $p=.8595$, in *ExMoney* $z=.983$, $p=.3257$; MWU-test for extensions per root in *ExLetter* $z=-0.309$, $p=.7573$, in *ExMoney* $z=.572$, $p=.5676$.

RESULT 3: *There are no differences in the innovative activity between treatments, meaning that H3a can be rejected. Introducing a subsidy leads to a shift from more sophisticated to basic innovations.*

5.3.2. Measures of welfare

In order to test for differences in welfare (H3b), three measures can be derived to gain a better understanding of the welfare within groups: first, the total gross value can be estimated, which comprises the value of all created innovations, i.e. the sum of all word values; second, the total net value additionally considers the investment, which includes the costs for the letters received for free (44 letters costing 4 tokens each) in *ExLetter*; and third, the relative net value (RNV) is used, as in Brüggemann et al. (2014). It includes the path dependency of the game from a myopic perspective, whereby creating a new word opens and closes different future innovation paths during the game. The RNV captures this dynamic element by giving a relative measure between the most and the less valuable innovation decision that each subject could have made in each specific situation of the game. Therefore, C_{it} is defined as the actual choice set for each subject i in period t defined by the letters owned by player i and the roots and extensions produced by all players at time t . The net payoff in each period $\pi(c_{it})$ is subsequently calculated for each choice $c_{it} \in C_{it}$ by deducting the investment in letters used and the license fees from the value of the new root or extension. The actual payoff π_{it} is then evaluated by using the maximum $M_{it} = \max\{\pi(c_{it}), c_{it} \in C_{it}\}$ and minimum $m_{it} = \min\{\pi(c_{it}), c_{it} \in C_{it}\}$ payoffs achievable from C_{it} . Hence, the relative net value RNV_{it} is computed as:

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

Note that $RNV_{it} \in [0, 1]$, $M \geq 0$ and $m \leq c \leq M$. Subjects should aim to maximize the RNV as it increases their payoffs. It is also a measure for subjects' performance conditional upon the opportunities that they have based upon the words already created in the game and the letters owned by each subject in any given situation.⁹ The findings for the three measures are summarized in table 4.

⁹ Note that the RNV is a measure for optimality from a myopic perspective and that the decision might not be optimal for the whole group. To measure the optimum for the whole group, all possible future innovation paths would have to be calculated for each word. This is obviously unrealistic for subjects given their cognitive abilities and thus it is not considered as a measure for the optimal choice. For an elaboration of this issue, see also Brüggemann et al. (2014).

Table 4. Different welfare measures by treatment and group

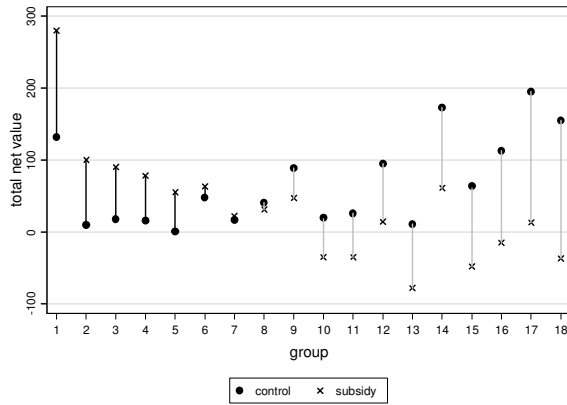
		<i>ExLetter</i>		<i>ExMoney</i>	
		<i>control</i>	<i>subsidy</i>	<i>control</i>	<i>subsidy</i>
total gross value	mean (sd)	311.11 (82.59)	317 (89.73)	297.16 (67.11)	295.95 (55.91)
	median	297.5	297	302	282
	min	197	200	186	192
	max	487	568	408	410
total net value	mean (sd)	68 (62.37)	33.67 (80.20)	58 (53.93)	29 (49.51)
	median	44.5	26.5	65	32
	min	1	-78	-54	-53
	max	195	280	127	124
relative net value (RNV)	mean (sd)	.475 (.084)	.460 (.070)	.464 (.064)	.425 (.057)
	median	.470	.489	.473	.417
	min	.316	.338	.338	.327
	max	.589	.566	.566	.569

Regarding the total gross value, there are no differences across treatments (WSR-test for *ExLetter* $z=-0.283$, $p=.7771$; for *ExMoney* $z=.543$, $p=.5869$).¹⁰ Figure 3 shows the total net value in detail, which corrects for the costs of the letters, including both the individually-bought letters and those received for free.

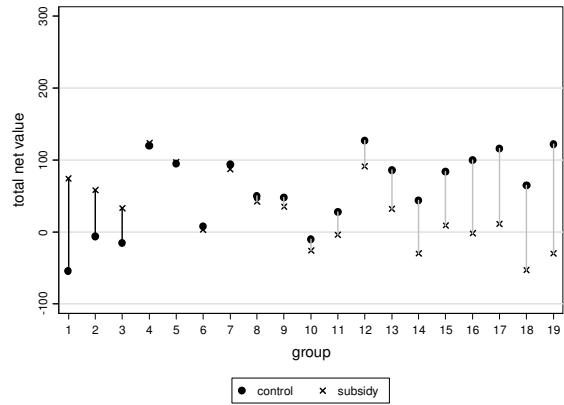
¹⁰ There are no differences due to the sequence order of the treatments, which is tested following the same procedure as described in chapter 5.1: MWU-test for the total gross value in *ExLetter* $z=0.000$, $p=1.000$, in *ExMoney* $z=1.266$, $p=.2055$; MWU-test for the total net value in *ExLetter* $z=-1.060$, $p=.2891$, in *ExMoney* $z=-0.653$, $p=.5136$; MWU-test for the RNV in *ExLetter* $z=1.192$, $p=.2332$, in *ExMoney* $z=.898$, $p=.3691$.

Figure 3. Total net value ordered by within-group difference for each treatment and experiment

a) *ExLetter*



b) *ExMoney*

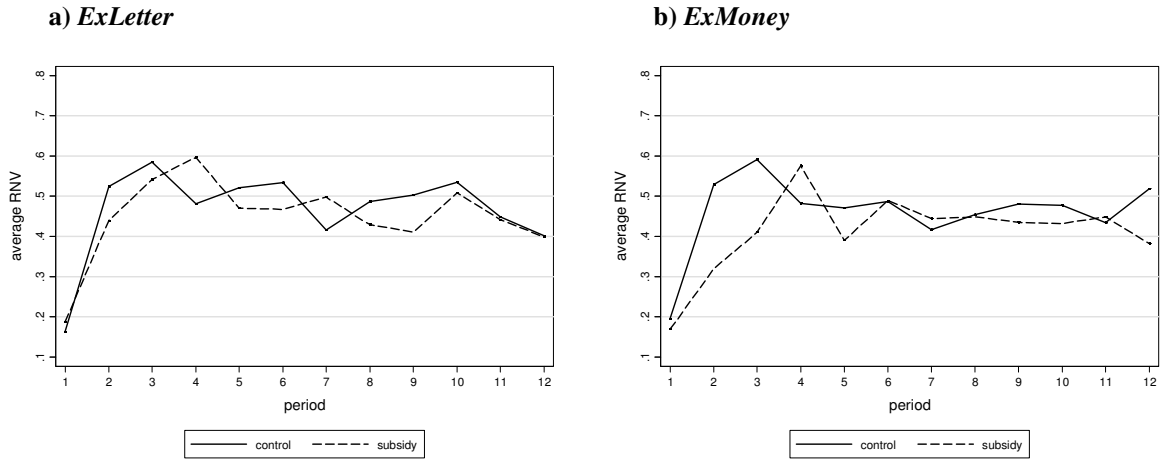


Note: The total net value is ordered by the differences of the groups between *control* and *subsidy* within each treatment and experiment. The distance between control and subsidy indicates the differences in performance within the same group in the two treatments. Black lines indicate that a group performed better in *subsidy*, while gray lines show that a group performed better in *control*.

In figure 3, it can be seen that groups react differently to the subsidy within each experiment: most groups (11 out of 18; 14 out of 19) perform better in *control* in both experiments (gray lines), in some groups the total net value does not differ and only few groups perform better in *subsidy* (7 out of 18; 5 out of 19). In sum, the total net value is significantly lower in *subsidy* in *ExMoney* (WSR-test $z=2.093$, $p=.0364$), while in *ExLetter* the difference fails to be significant (WSR-test $z=1.372$, $p=.1701$). Nevertheless, in *ExLetter* in *subsidy* around 33% and in *ExMoney* around 28% of the groups yield a negative total net value, which means that they were unable to create innovations amounting to the sum of their investments. This also occurs in around 22% of the groups in *control* in *ExMoney* but in none of the groups in *control* in *ExLetter*.

These findings remain robust when path dependency is included by using the RNV, which integrates a myopic perspective. As a relative measure it can decrease during the game, in contrast to total gross value and the total net value. This might be true if subjects are unable to choose the best opportunity to innovate from the existing words and letters in the respective period. Figure 4 shows the development of the average RNV over periods for both experiments.

Figure 4. Average RNV over periods by treatment



Regarding the RNV, there are no substantial differences across treatments during the course of the game in *ExLetter* (WSR-test $z=.544$, $p=.5862$). In *ExMoney*, subjects perform better in *control* (WSR-test $z=1.771$, $p=.0766$). In all treatments, the RNV increases at the beginning of the game. Subsequently, due to the increasing number of potential extensions, subjects become less successful in choosing the most profitable options, which leads to a slight decrease in the average RNV.

In sum, subsidies do not have a positive effect when considering three welfare measures. In fact, in *ExMoney*, when considering the total net value and the RNV, subjects perform worse when introducing a subsidy. In *ExLetter* in *subsidy*, one-third of the groups fail to generate positive welfare gains altogether. These findings can be understood from an individual perspective, given that subjects maximize their incomes while simultaneously reducing their effort within the game. Consequently, subjects refrain from maximizing their incomes – i.e. trying to be as innovative as possible by using the additional resources – but are rather content with receiving subsidies and realizing a reduced effort. While this is individually rational if payoff maximization is not the most important individual goal, this behavior does not maximize overall welfare. Recall that welfare is defined as the sum of the value of all innovations created during the course of the game. Thus, measures leading to reduced collective innovative efforts and productivity by definition reduce overall welfare. From a welfare perspective, this effect occurs in the experiment, since subsidies lead to a lower total net value created in *subsidy* and a lack of additional gains in innovativeness, as indicated by the lower RNV. Furthermore, it could be argued that the costs for implementing the subsidies – e.g. by the state – have not been captured by the definition of welfare used in this paper. Thus, taking into account the actual costs incurred by the implementation of large-scale subsidies would diminish the welfare effects of allocating subsidies even further.

RESULT 4: *H3b can be rejected as subsidies fail to increase both the individual innovativeness and the overall welfare.*

6. Conclusion

In this study, laboratory evidence is presented concerning the effects of subsidies in stimulating private innovative activity. An experimental approach introduced by Crosetto (2010) is used and modified, which implements the features of risky investment, creativity and ownership in a laboratory experiment that simulates a cumulative innovation process. Therefore, this experimental design allows adding counterfactual evidence to the existing literature on the effects of public subsidies (Zúñiga-Vicente et al. 2014). Two specific situations in the continuum from restrictive grant-in-aid to freely-usable monetary subsidies are applied, namely through additional material resources and a direct monetary subsidy.

The main findings of this study are that subsidies neither increase private innovative activities nor overall welfare. Furthermore, the investment behavior changes with a subsidy and a substantial crowding-out of private investment occurs. While subjects individually increase their incomes due to the higher endowments with subsidies, their innovation output remains unchanged in both experiments. Moreover, the kind of innovations produced changes due to the subsidy, whereby more basic innovations are created, which are less desirable from a welfare perspective than more sophisticated innovations. In turn, the cooperation behavior – as measured by the level of license fees chosen – does not change due to subsidies.

When taking into account different welfare measures, none of them show a positive effect of subsidies on the overall welfare. Following the individual results, subjects' behavior is influenced by the kind of subsidy: when including the costs of a subsidy incurred by the state, the overall welfare decreases in the experiment with a direct monetary subsidy and remains stable in the experiment with additional material resources. Therefore, it can be concluded that subsidies distributed in the form of additional material resources fail to increase welfare, while direct monetary subsidies even have a negative impact. Overall, these results support previous studies arguing that subsidies have little or even negative effects on the innovative activity by failing to increase innovativeness or producing a crowding-out of private investment. Accordingly, due to the additional costs to the state and the doubtful benefits, public subsidies as a policy instrument to foster private innovation might need to be called into question.

While this study has been able to yield novel empirical evidence, it also has several limitations, which should be taken into account in future studies. Regarding the experimental design, technological breakthroughs are not included; thus, only incremental, sequential innovations

are modeled, which limits the applicability of the results to specific innovative settings. Regarding the treatments, only two particular kinds and amounts of subsidies are tested, whereby further studies might test different specifics of innovation subsidies in a laboratory environment. Moreover, the additional costs that the state would have to bear for implementing and distributing the subsidies cannot be considered in this setting; accordingly, further studies might include the approximate costs of introducing and distributing subsidies and thus provide an estimation concerning when the benefits of innovation subsidies exceed the costs incurred by the state.

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Appendix A - Instructions for all treatments

In general, the control treatment is described, which is the same in both experiments. The differences between treatments are indicated in square brackets, whereby the subsidy treatment of ExLetter is denominated as ‘extra letter’ and the subsidy treatment of ExMoney as ‘extra money’. Furthermore, the order (first, second) in which the treatments were conducted is indicated. 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.

[*extra letter, first*: At the end of your turn, you will additionally receive one letter for free.]

[*extra money, first*: At the end of your turn, you will receive 4 tokens, i.e. the value of one letter, for free.]

You will play in a group of 4 players.

The Payoff

Your payoff depends on the sum of the value of your letters, which is calculated in experimental tokens. One token is converted to €0.10 at the end of the experiment. You start this part of the game with an endowment of 50 tokens. Note that it is possible to finish the experiment with less than your starting endowment.

Please note the table below, which contains all letters, their value (in tokens) and the frequency with which they occur in the game.

Table 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: value of the word, amount of license fees, the player who produced the word,

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

Statistics
Information on the current payoff, period, letters left in the game , etc.

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

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

The screenshot shows the game interface for 'Spieler 1 - Runde 5'. It includes several panels:

- Statistics:** Shows 'Verbleibende Buchstaben: 176', 'Guthaben: 61.5', and 'Auszahlung in dieser Runde: 3.5'.
- Bisherige Wörter aller Spieler:** A table listing words, their values, license fees, and the player who produced them.

Wort	Wert	zu zahlende Lizenz	gelegt von	Lizenzgebühr der letzten Erweiterung
aus	2.4	0	Spieler 2	0%
aus	6	0	Spieler 1	0%
aus	5	1.0	Spieler 2	0%
aus	4	2.9	Spieler 1	0%
aus	4	0	Spieler 2	0%
aus	4	0.7	Spieler 1	0%
aus	3	1.5	Spieler 2	0%
aus	7	0	Spieler 1	0%
aus	5	1.5	Spieler 2	0%
- Eigene Wörter:** A table showing the player's own words.

Wort	Wert	Einkünfte
aus	3	1.5
aus	7	3.5
- Eigene Erweiterungen:** A table showing the player's own extensions.

Wort	gezahlte	Einkünfte
aus	0	2.4
aus	0	1.5
- Game Log:** A scrollable log at the bottom showing the game's progress, including word production, license fees, and player actions.

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

Game Log
Documentation of all players' activities.

Course of a Turn

When it is your turn, a dialog pops up asking you for choices. You have 60 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 five phases:

1. Word phase I

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. Each letter can only be used once: after producing or extending a word, the letter will be deleted from your list.

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 by typing the letters on your keyboard.
The payoff that 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).

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 'last', 'rast' and 'aste', and 'last' again into 'laust' and this into 'klaust'. 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 'laust', 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.

2. Royalty phase I

Your activity: Setting a royalty fee

After producing a word, you have to decide whether or not to set a royalty fee that other players are required to pay when creating extensions. If you set a royalty fee, you will have to choose between 10 and 100 percent of the value of the word.



If another player extends your word, the fee is automatically transferred to you.

In the following, you can find three examples for others extending your word:

- If you choose no license fee, the word is entirely free to use for the other players. They will receive the entire value of the word.
- At 100 percent, you will receive the initial value of the word and 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 other player will receive 80 percent plus the value of their added letter.

The word and the royalty fee remain fixed during the entire game. Both appear on the list of public words on the main board and can be used by all other players. However, other players are required to pay the respective royalty fee when extending the word.

Furthermore, you will have to decide whether to set a royalty fee if you extend a word with a single letter. In this case, you only decide on the fee for your added letter.

3. Word phase II

After the first license phase, a second word phase ensues, in which you can produce another word following the procedure described above.

4. Royalty phase II

If you have produced or extended a second word, you will have to decide once again whether to set a royalty fee or not and – if so – determine the level of the royalty fee as described above.

5. Buying phase

Your activity: Buying letters

You can choose to buy no, one or two letters at the price of 4 tokens for each letter. The order of the letters has been randomly determined prior to the game by sampling without replacement from the list of letters shown on the table on page 1. At the beginning, you are provided four letters and 50 tokens

[*extra letter, first*: and in each turn one additional letter in the buying phase]

[*extra money, first*: and in each turn four additional tokens in the buying phase] for free.

After that, your turn ends and it is the next player's turn. The game is played for 12 periods. Finally, some examples for the calculation of your payoff are provided:

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 'hast' (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 'hast':

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 'hast'. If player 3 then extends 'hast' into 'haust', 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

Once the participants of a session had finished the first part, they were handed out the second part of the instructions:

Hereafter, you will play the game again with the following changes:

- You receive again 50 tokens. Your payoffs will be aggregated at the end of the experiment.
- The groups are matched randomly.
- [*control, first; extra letter, second*: In the buying phase at the end of your turn, you receive a free letter in each turn and you can only buy one additional letter.]
[*control, first; extra money, second*: At the end of each turn, 4 tokens are added to your endowment, which amounts to the cost of one letter.]
[*extra letter, first; control, second*: In the buying phase at the end of your turn, you no longer receive a free letter anymore; instead, you are now able to buy two, one or no letters.]
[*extra money, first; control, second*: In the buying phase at the end of your turn, it is no longer the case that 4 extra tokens are added to your endowment.]

Apart from these changes, all parameters of the game remain constant.

Appendix B - Instructions for the control task

Note: The instructions for the word task were shown to participants on the 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 pressing 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 3 minutes have expired, the test will end and you will be shown your results.

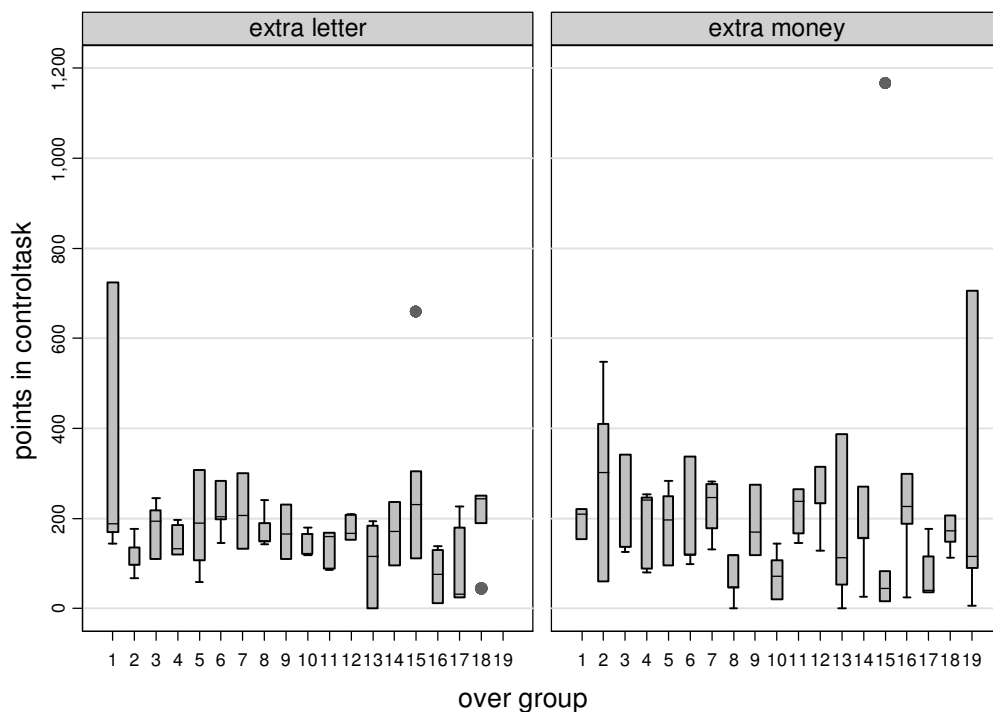
As soon as you enter the next screen, the timer will start ticking.

To proceed to the next screen, please press the letter 'R' on your keyboard.

Appendix C – Performance in the control task

To test for individual task-specific knowledge, a control task is run prior to the experiment. Therefore, the word task by Eckartz et al. (2012) is implemented, in which subjects are asked to build as many words as possible out of the letterset *accehhikllst* within three minutes. The instructions for the control task are provided in appendix B. For every word that they create, subjects earn points, whereby the number of points increases disproportionally with the word length: a word with three letters generates 6 points, a four-letter word 10 points, a five-letter word 15 points, etc. Overall, given the letterset, 330 different words can be generated, which are worth 5,585 points. In each session, the five subjects scoring the most points were awarded an additional 1€ to their overall payoff. The distribution of the groups' performance across treatments – as measured by the points achieved – is provided in figure A.1.

Figure A.1. Performance in the control task by group and treatment



At the group level, there is some heterogeneity in the task-specific skills, yet no substantial differences when compared across experiments (MWU-test *extra letter* vs. *extra money* $z=-1.216$ and $p=.2242$). Accordingly, it can be assumed that these results are not driven by subjects' systematically different abilities in creating words across the two experiments.