The Impacts of R&D Contest on Research Activities: An analysis of RoboCup

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Abstract— R&D contests have gained popularity in recent years. Empirical studies have, however, scarcely investigated their impacts on research activities to date. This study empirically analyzes the impacts of RoboCup, a robot soccer competition, to researchers' performance in general. The results show that both contest participants and non-participants benefit from it.

Introduction

Governments and other organizations have been increasingly interested in research and development (R&D) contests in recent years[1]. Witnessing the apparent success of recent cases such as U.S. DARPA's Grand Challenge or the Ansari X Prize, academic researchers have also begun initiating R&D contests in the recent years. However, to the best of this author's knowledge, [2] is the only study that has empirically and systematically examined the impacts of R&D contests on research activities. [2] examined a contest for the agricultural machinery in the U.K., which was initiated in 1839 and continued until 1939. With the exception of this study, there only exist oft-mentioned successful cases and a few case studies[3–5]. [3] examined three contests in the last century and concluded that the contests not only promoted innovative activities of sponsor interest but helped develop relevant industries as well. [4] and [5], who examined the recent two contests in space technologies and the contest initiated by the UK parliament in the eighteenth century, respectively, reached similar conclusions. Past successful contests have been designed and held in the later stages of R&D activities close to commercialization, however.

R&D contest is an attractive scheme for governments and researchers. The outcome of the contest is clear and tangible. So are the awarding criteria. The sponsor can avoid the costly and time-consuming process of selecting research projects to fund, which is necessary under the traditional R&D grant system. In typical contests, the sponsors are only responsible for the one-time cash awards for winners. They do not have to fund the contest participants' R&D activities, which can be many times as large as the cash award. It is the participants that are responsible for funding their research activities for the contests. While governments and academic researchers have become increasingly interested in R&D contests recently, there is no evidence that R&D contests are effective in the basic or applied R&D stages.

This study aims to fill these voids by providing empirical evidence of the impacts of R&D contests on research activities. It particularly focuses on an R&D contest in the basic-to-applied R&D stage, where success is not accompanied by direct monetary rewards. This is a common format for contests initiated in academia. For analysis, this study takes a bibliometric approach and analyzes the research performance of the participants of the RoboCup Soccer contest. It is an R&D contest in robotics, the goal of which is to build a robot soccer team that is capable of playing with human teams by 2050. The RoboCup Soccer contest has been held annually since 1997 and has been growing to date.

This study firstly found that R&D contests seem to have clearer impacts on research productivity than on research quality. Secondly participation has negative impacts on research performance in the short term but that the impacts turn positive in the subsequent years. In addition, repeated participation has positive impacts. Thirdly, researchers who do not participate in RoboCup themselves but publish a scholarly paper(s) with RoboCup participants exhibit higher research performance than those who do not. It indicates spillover effects of R&D contests to the larger research community. The findings seem encouraging for policy makers and researchers who are interested in R&D contests since they have the potential to facilitate not only targeted research but research activities in general.

Data and Sample

Data of the RoboCup Participants

This study analyzes the RoboCup Soccer competition (or simply "RoboCup" hereafter). RoboCup has steadily grown since its creation. At RoboCup 2012, 145 soccer teams participated in the games, a remarkable increase from 38 teams in 1997. The popularity of RoboCup provides an opportunity to examine the roles and impacts of R&D contests in basic and applied R&D stages.

In RoboCup, each team participating in the soccer games is obliged to submit a short team description paper (TDP) to disseminate technical information about their robots or programs. Along with the soccer games, a regular academic symposium is held, in which papers selected from all of the submissions to the symposium are accepted as symposium papers (SPs) based on scientific merit and included in the symposium proceedings. The symposium proceedings keep non-technical, non-research overview papers (OPs) as well. The OPs provide the goal, rules or overview of the RoboCup contests and summarize the results of the games. This study collects information about RoboCup participants in 2001-03 from the TDPs, SPs and OPs, which is supplemented with the participation data of the RoboCup contests held in 1997 (the first contest). This study collected the SPs, OPs, and TDPs from the symposium proceedings. It extended the collection process to a supplementary CD-ROM that keeps TDPs for the RoboCup 2003 and the Internet search for the RoboCup 2002. Then, it cleaned and organized the collected authorship data.

Bibliometric Data

The study collected the bibliometric data of the papers published in academic journals in robotics to measure the performance of individual researchers. The data is used not only to measure the research performance of researchers but to identify researchers who are not participating in the RoboCup contest as well. These researchers are used as a comparison group in the analysis.

The data are obtained from Thomson Reuters' Web of Science database in November 2011 for 18 major academic journals in robotics published in 2001-05, in which not only the RoboCup participants but also robotics researchers in general publish or cite papers most frequently (WoS data). The WoS data were then organized and matched with RoboCup participants. The resulting sample consists of 14,033 researchers, among whom 1,010 researchers participated in RoboCup 2001-03 as TDP and/or SP authors. About 13,000 researchers in the sample did not participate in these RoboCup contests but published at least one paper in the 18 journals between 2001 and 2005.

Analysis

This study carried out a series of statistical analysis to examine the impacts of the RoboCup participation on research performance, particularly research productivity and research quality.

Dependent variables

The study uses two dependent variables to measure research performance in terms of research productivity (quantity) and quality following the literature on patenting and paper publishing performance[6–9].

Research productivity is measured in terms of the number of academic papers published in the 18 journals listed in Table 1 between 2004 and 2005. Researchers who published many papers are more productive than those who did not. Thus, it is natural to use the proxy to measure the research productivity of researchers. The RoboCup contest is usually held in summer every year. The submission of the papers and the registration of the contests are closed a few months in advance. It is, therefore, necessary for the prospective RoboCup participants in either TDPs or SPs to be engaged in the research and in the assembling of robots several months in advance if not within one year. They might have gained new ideas or insights about certain research possibilities through the months-long preparation and through their participation in the RoboCup around summer. The new insights they might have gained would have been incorporated in their new research then.

Table 1. *Journals used in the analysis*

Journal title
Advanced Robotics
Artificial Intelligence
Automatica
Autonomous Robots
Biological Cybernetics
Fuzzy Sets and Systems
IEEE Robotics & Automation Magazine
IEEE Transactions on Automatic Control
IEEE Transactions on Neural Networks
IEEE Transactions on Robotics and Automation*
IEEE Transactions on Robotics*
IEEE Transactions on Systems Man And Cybernetics, Part B
IEEE/ASME Transactions on Mechatronics
International Journal of Robotics & Automation
International Journal of Robotics Research
Journal of Intelligent & Robotic Systems
Robotica
Robotics and Autonomous Systems

* IEEE Transactions of Robotics and Automation was replaced by IEEE Transaction of Robotics in 2005.

Research quality is measured in terms of the number of forward citations that the papers published between 2004 and 2005 received from those that were published in subsequent years. High research productivity does not necessarily mean high quality of research. This study uses forward citation as proxy of the quality of research. Researchers refer to past literature in their papers if the literature is relevant and important in their study. Papers that may be able to help advance relevant research fields and that have huge impacts are more likely to be cited by subsequent papers. There is a lag time between when a paper appears in a journal and when it is cited by others, however. Sometimes, researchers may need more time to grasp the gist of a paper that they have read. They may also need more time before they can apply the newly acquired knowledge on their own research activities. Moreover, they may need ample time to evaluate the effectiveness of their newly acquired knowledge. If they judge the paper as valuable, they may cite it in the next papers that they write, which may appear in a journal only after several months or so.

Explanatory variables

Repeated SPs authorship is a dummy variable and takes 1 when a researcher participates in RoboCup 2001-03 twice or more. It takes 0 otherwise.

SP 2003 is the number of the symposium papers (SPs) that participants submitted and included in the symposium proceedings for the symposium that was held during the RoboCup 2003 contest. *SP 2003* takes a value of either 0 (i.e. no SP) or 1 (i.e. one SP) for the sheer majority of researchers. Few participants published more than one SP. Similarly, *SP 2002* and *SP 2001* are the number of SPs that were included in the symposium proceedings for the RoboCup 2002 and 2001 contests, respectively.

Collaboration with RoboCup participants is a dummy variable and takes 1 when a researcher does not participate in RoboCup him/herself but publishes a scholarly paper(s) which is co-authored with a RoboCup participant(s). It takes 0 otherwise. The variable is to assess the spillover effects of R&D contests to the larger research community.

Control variables

Seventeen control variables are also included in analysis to control for soccer leagues and years, first-mover advantage from the participation in the first RoboCup, baseline of research performance, etc.

Table 2. *Summary statistics (n=14,033)*

Variable	Mean	Std. Dev.	Min.	Max.
Research productivity	0.69	1.35	0	24
Research quality	13.35	42.86	0	1,498
Repeated SPs authorship	0.00	0.07	0	1
SP 2003	0.01	0.14	0	3
SP 2002	0.01	0.10	0	3
SP 2001	0.01	0.14	0	4
Collaboration with RoboCup participants	0.02	0.13	0	1

Analysis results

The dependent variables—*Research productivity* and *Research quality*—are non-negative count data of papers and forward citations with wide variance, respectively. A negative binomial model is applied to address the over-dispersion in those variables[10], [11]. In addition, robust standard errors were used to address the heteroscedasticity in the data for analysis.

Tables 2 and 3 provide descriptive statistics of the dependent and explanatory variables and the correlation matrix. Estimations were made with Stata 12. Table 4 presents the estimation results for a full model. Only the results for main explanatory variables are shown there due to space limitation. Firstly, R&D contests seem to have clearer impacts on research productivity (Model 1) than on research quality (Model 2). A larger numbers of coefficients for explanatory variables are found significant in Model 1 than in Model 2. The signs of coefficients are same in both Models.

The coefficient for *SP 2003* is negative and significant in Model 1 while it is negative but not significant

Table 3. *Correlation among dependent and explanatory variables (n=14,033)*

	Variable	1	2	3
1	*Research productivity*			
2	*Research quality*	0.462		
3	*Repeated SPs authorship*	-0.016	-0.018	
4	*SP 2003*	-0.034	-0.022	0.504
5	*SP 2002*	-0.016	-0.018	0.556
6	*SP 2001*	-0.023	-0.025	0.502
7	*Collaboration with RoboCup participants*	0.029	0.028	-0.009

	Variable	4	5	6
5	*SP 2002*	0.248		
6	*SP 2001*	0.267	0.272	
7	*Collaboration with RoboCup participants*	-0.014	-0.011	-0.013

in Model 2. The coefficients for *SP 2002* and *SP 2001* are positive and significant in Model 1 while they are positive but not significant in Model 2. They suggest that participation has negative impacts on research performance in the short term but that the impacts turn positive in the subsequent years.

The coefficient for *Repeated SPs authorship* is positive and significant in Model 1 while it is negative and insignificant in Model 2. Repeated participation leads to higher productivity while it may not necessarily be translated to high-quality research, which other researchers regard as new and important.

The coefficient for *Collaboration with RoboCup participants* is positive and significant in both Model 1 and 2. That is, researchers who do not participate in RoboCup themselves but publish a scholarly paper(s) with RoboCup participants exhibit higher research performance than those who do not. It indicates spillover effects of R&D contests to the larger research community.

The findings seem encouraging for policy makers and researchers who are interested in R&D contests since they have the potential to facilitate not only targeted research but research activities in general.

Table 4. *Negative binomial regression of research performance*

Variable	Model 1 (Research productivity)	Model 2 (Research quality)
Repeated SPs authorship	2.01***	-0.34
	(0.77)	(0.88)
SP 2003	-2.26*	-2.64***
	(1.17)	(0.70)
SP 2002	1.95***	0.76
	(0.68)	(0.67)
SP 2001	1.76***	0.6
	(0.56)	(0.62)
Collaboration with RoboCup participants	0.28**	0.41***
	(0.11)	(0.14)
N	14,033	14,033
Chi^2 value of Wald test	219.34	510.66
Log-likelihood	-15,006.81	-37,279.87

Robust standard errors in parentheses

* p<0.10, ** p<0.05, *** p<0.01

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