Who Speaks for Innovations?: An Analysis of the Media Exposure of R&D Outputs

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Abstract

The literature in research policy extensively addresses the interaction between public R&D and the society. Scholars have paid particular attention to the way science and technology are diffused into the society and industry with the aim of substantiating their potential value. In practice, having recognized the importance of the said interaction, R&D entities and governmental organizations promote scientific and technological innovations that result from their R&D activities. Yet, the nature of news media exposure as their primary channel to promote R&D outcomes has been remarkably understudied. Using the results of R&D projects supported by the National Research Foundation of Korea (NRF), this study examines R&D entities' strategic use of the news media to publicize their outcomes. The empirical results suggest that the scale of an R&D project positively affects the counts of media exposure of its R&D outcomes, whereas the level of technology readiness and the technology life-cycle do not have significant influence. In addition, the results suggest that, compared to senior researchers, young researchers are more likely to publicize their R&D outcomes and that R&D outcomes from highly ranked universities are more likely to be publicized than those from lower-ranking universities despite our control for R&D outcomes. The aforementioned results suggest that in promoting the diffusion of science and technology, especially to the public, policymakers should be concerned about incentives for those who provide techno-scientific information, such as researchers. The social need for the diffusion of techno-scientific information into the public (e.g., technology transfer and diffusion) is an insignificant factor in determining the media exposure of such information, whereas personal benefits and sensitive issues related to a researcher's own R&D activities (e.g., justification for R&D activities) drive researchers to publicize their R&D outcomes. This paper suggests that policymakers, especially those concerned with better diffusion of scientific and technological innovations need to design a proper incentive system to maximize the societal benefits of media exposure.

Keywords
research and development strategy, knowledge diffusion, media exposure of science and technology, science and technology communication

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1. INTRODUCTION

A number of scholars have emphasized the importance of scientific and technological innovations in the knowledge economy, arguing that such innovations in the public sector eventually improve the competitiveness of firms and nations (Bush, 1945). Given the said importance, most governments have established and executed diverse initiatives for strategic investments in science and technology, and scholars have explored processes by which scientific and technological innovations can be transferred into the society and industry. In doing so, scholars have focused on how the inbound and outbound linkages of R&D entities can be vitalized (Bauer, Allum, & Miller, 2007; Roberts, 2000).

As one of the outbound linkages, communication through media, especially the news media, has been considered an effective means of bringing R&D entities closer to the public (Bauer et al., 2007; Besley & Shanahan, 2005; Hijmans, Pleijter, & Wester, 2003; MST, 2001). By reaching the news media, R&D entities not only expose themselves to those outside their R&D network, but also, in the process, inspire other R&D entities to join and/or interact with their technological paradigms. Moreover, the media exposure of techno-scientific innovations to the public may contribute to creating a societal environment favorable to further development of their innovations. Such an environment enhances the impact of innovations and exerts a positive impact on the national economy in the long run (Besley & Shanahan, 2005; Hijmans, et al., 2003; MST, 2001; Winter, 2004).

In fact, governmental organizations for science and technology research encourage R&D entities to publicize their outcomes through the news media. For instance, in South Korea, researchers are required to provide reports on media exposure of their discoveries and inventions to indicate the societal impact of their R&D results as part of evaluation processes. As a result of this policy, the past several decades have seen an increase in the number of articles on science and technology across the news media (Pellechia, 1997), with over half of them reporting the latest innovations from R&D entities (Kim, 2008).

However, the context in which information about scientific discoveries and technological inventions is made available to the public through the news media remains remarkably understudied. Previous studies on the topic are limited in scope and only help understand how the public or the media perceive news on techno-scientific innovations. That is, the literature lacks understanding as to what drives such news reports. Given that the media rely heavily on researchers and other sources of information in order to collect data for news on science and technology, R&D entities' reasons for generating media exposure are the key to understanding how the news media shape the societal impact of science and technology. Much of the literature suggests that researchers not only follow the norms of the scientific community but are also responsive to economic gains (Stephan, 2012), which implies that they may contact the news media for strategic purposes.

The purpose of this study is to unravel the strategic contexts for media exposure whereby R&D entities and personnel promote their scientific discoveries and technological inventions. More specifically, this study investigates whether the aim of media exposure lies in reducing transaction costs inherent in their search for other entities that can realize the potential values of their innovations, an activity that increases the societal impact of techno-scientific innovations from the public sector. Furthermore, this study uncovers whether researchers use the news media to enhance their reputation, which is essential for maintaining their academic positions and securing further research opportunities.

This study examines which strategic contexts influence social recognition of innovations. In other words, it elucidates factors explaining the discrepancy between the actual and socially recognized landscapes in techno-scientific innovations. This implication is of particular interest to policymakers, who often rely on the social recognition of techno-scientific issues in sensing the degree and direction of innovations across all techno-scientific fields. After all, the news media, which form the critical basis of the symbolic and subjective reality in the minds of the public and policymakers, can significantly affect further decisions regarding the scope and direction of R&D projects as well as their conductors.

The remainder of this paper is organized as follows. Section 2 discusses the definition and mechanisms of media exposure, the strategic contexts for media exposure, and our hypotheses. The data analyses in Section 3 and the empirical methodology in Section 4 are followed by a discussion of the results in Section 5 and concluding remarks in Section 6.

2. THEORETICAL BACKGROUND AND HYPOTHESES

2.1. Definition and Mechanisms of Media Exposure

Scholars who studied the interaction between the science community and the news media defined it as a phenomenon of science communication. This definition denotes the skills required to create awareness, enjoyment, interest, opinions, and understanding of science and technology through the news media, conversations, or behaviors (Burns, O'Connor, & Stocklmayer, 2003). The term 'media exposure' refers to the process of publicizing science and technology through media, which enables researchers to publicize their opinions or news mainly to the public and possibly to other R&D entities and policymakers.[1]

Among the various types of news offered to the public, R&D outcomes are generally distributed by three parties: researchers, public information officers, and journalists (Dunwoody, 1986; Nelkin,

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[1] As a matter of fact, media is not the main channel through which researchers communicate with external entities (Cohen, Nelson, & Walsh, 2002). Yet, using media can help them find entities that researchers would not be able to approach otherwise.

1995; Rogers, 1985; Weigold, 2001). By delivering news with regard to R&D outcomes, they determine the content of information as well as the frequency of exposure in each organizational and strategic context (Shoemaker, 1991).

To begin with, researchers generally report their scientific and technological innovations to public information officers in charge of public relations[2], who typically work in the same organizations as them. Indeed, researchers can contact journalists directly, or journalists themselves can seek researchers related to the latest scientific and technological issues. However, since the social ties between researchers and journalists are weak, researchers tend to rely on internal public relations professionals (i.e., public information officers) when publicizing their R&D outcomes (Dunwoody & Ryan, 1983). In fact, the division of labor in promotion of R&D outcomes has become a common practice in research organizations. By 1983, 92% of all American public research organizations had independent departments of public relations (Dunwoody & Ryan, 1983). Based on internal reports from researchers, public information officers write information subsidies (i.e., press releases) and distribute them to the press (Gandy, 1982). Therefore, the structural characteristics of each organization affect the form and direction of its public relations (Rogers, 1985).

As a gatekeeper of information[3], the press screens collected information according to 'news value' and decides which topics are to be publicized (Shoemaker, 1991).[4]

2.2. Contexts for Media Exposure of R&D Outcomes

Research organizations publicizing their R&D outcomes have strategic concerns about their message receivers (Shoemaker, 1991). On the surface, the conventional gatekeeping structure allows the press to manipulate media exposure. However, in the case of scientific and technological news, researchers and public information officers (hereafter collectively referred to as information providers) control the system. There are two reasons for their dominant roles in media exposure; not only are the sources of techno-scientific information limited but also the information provided is too esoteric for non-researchers to interpret (Dunwoody, 1986). Therefore, despite the large number of news articles from the press, the support of information providers is vital in delivering news on cutting-edge science and technology (MST, 2001; Petersen, 2001).

Since both researchers and public information officers affect the content and counts of media exposure of R&D outcomes (Petersen, 2001), in order to understand the nature of media exposure, the

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2 Other recipients of information include public information officers at governmental organizations that provide funding.

3 This gatekeeping role is performed not only by editors but also by journalists and even by public information officers within research organizations (Gandy, 1982).

4 In the process of gatekeeping, techno-scientific impact is not the only factor to be considered. Other salient factors include news values, indicative of the degree of attention expected from the public (Aronoff, 1975). In general, news values are determined by diverse factors such as human interest and eminence (Blake & Haroldson, 1975). Thus, an assessment of news values tends to be quite subjective (White, 1950).

following viewpoints must be considered: The characteristics of R&D activities and R&D entities. The next sub-chapter reviews the contexts for media exposure of R&D outcome from these perspectives and develops hypotheses based on them.

2.2.1. The Impact of R&D Activities

Technology Readiness Level (TRL)

An R&D process starts with an initial idea, which is then realized. While public research organizations, especially universities normally conduct basic research, firms develop commercial technology. Given this, university-to-industry knowledge transfer has been considered an effective means to improve the utility of science and technology (Bozeman, 2000). Therefore, when evaluating R&D projects aimed at contributing to industry and society, governmental organizations place a great emphasis on knowledge transfer records and use them as performance measures. In turn, R&D entities follow evaluation guidelines (Butler, 2003; Moed, 2008) and attach importance to knowledge transfer. In addition to securing proof of performance, researchers can enjoy financial benefits through technology transfer by granting other entities the right to use their intellectual property (Bozeman, 2000).

Despite its merits, technology entails significant search costs (Arora, Forfuri, & Gambardella, 2001). Thus, a number of public research organizations have publicized their R&D activities through their own Technology Transfer Office (TTO) and public relations departments to market their technology and raise their profiles.

Media exposure of R&D outcomes can significantly alleviate search costs required for technology transfer. Although firms can afford access to such academic media such as journals and conferences, the cutting-edge information provided is mostly codified in academic jargon and requires in-depth complementary analyses, making it costly and difficult for firms to interpret its utility. Likewise, although patent information can be accessed at a low cost, in many cases, efforts to maximize the scope of technology render the information provided highly cryptic (Durack, 2004). On the contrary, the news media generally use universal terminology to address techno-scientific information, which then leads to a much greater impact, especially on non-academic organizations and the public. Therefore, publicizing R&D outcomes through the news media is key to establishing trust and a good rapport with external organizations, which has the potential to create mutual benefits in the form of information sharing and technology transfer (Kramer & Wells, 2005).

In particular, R&D outcomes with a high level of technology readiness (i.e., close to the commercial stage) enjoy more media exposure. Given the uncertain nature of commercialization, the majority of firms pay more attention to quickly applicable knowledge. Furthermore, R&D activities with a high level of technology readiness are generally designed for commercial use, which draws interest from firms. Thus, R&D entities (i.e., researchers and research teams) that conduct commercially driven R&D activities are more likely to be concerned with media exposure than those who conduct R&D activities with a low level of technology readiness.

Hypothesis 1: There is a positive correlation between the technology readiness level of an R&D activity and media exposure.

Technology Life Cycle

Another notable feature in the contexts for media exposure is the technology life cycle, which describes both the evolution of technology within the technological paradigm and corresponding changes in competitive environments.[5] Technological innovations tend to follow patterns of evolution, similar to the competitive dynamics among R&D entities (Nieto, 1998). In the early stages of the technology life cycle, various technology/product designs with unsatisfactory technological performance are identified. Next, the designs compete with one another to take the lead within the technology paradigm (Nieto, 1998). Then, in the late stages of the technology life cycle, dominant designs emerge, and as a result, fewer competitors survive compared to the early stages. This reduced level of competition undermines the intensity of innovation activities. Moreover, the possibility of making technological improvement remains low (Nieto, 1998). Therefore, as a technology undergoes its life cycle, it becomes less urgent to acquire domination within a techno-scientific paradigm, and concurrently, R&D entities become less motivated to seek innovative partnerships for commercialization.

Media exposure can be more intense in the early stages of the technology life cycle. Since media exposure enables R&D entities to reach both the internal society and the external partakers of science and technology (e.g., industry, the public, and policymakers through opinion forming) they can achieve dominant positions within relevant paradigms. Given that social interaction with other players within a certain paradigm helps secure a dominant position within it (Geels & Schot, 2007), efforts to raise awareness of R&D outcomes may inspire other R&D entities and enhance the co-evolution of science and technology by expanding the scale of each techno-scientific platform. The advantage of media exposure, which has a wider sphere of influence than academic media, can be said to be more prominent in the early stages of the technology life cycle than in the late stages. It is most urgent in the early stages to acquire domination within a techno-scientific paradigm. Thus, R&D entities have higher incentives to publicize their R&D outcomes in the early stages of the technology life cycle.

A consideration of news values shows the same pattern. R&D outcomes within a new techno-scientific paradigm are likely to receive more attention from the public, since they present a new approach to existent problems not yet tackled or resolved by previous or obsolescent paradigms (Kuhn, 1996). In fact, the news media perceive science and technology as revolutionary and magi-

[5] One could argue that science as a body of knowledge does not follow the technology life cycle. However, the systemic view of the interactions between science and technology reveals that science and technology complement each other with their boundaries intersected (Debackere, Verbeek, Luwel & Zimmermann, 2002); thus, scholars have sought a methodology to measure the evolution of science and technology (Debackere, et al., 2002).

cal solutions (Nelkin, 1995). In response to human interest, which is a key factor in news values (Blake & Haroldson, 1975), gatekeepers prefer to select news items in the early stages of the technology life cycle. Meanwhile, R&D outcomes in the late stages of the technology life cycle produce less novelty because of the relatively higher public awareness of their technology, and consequently they hold less news values.

Hypothesis 2: There is a negative correlation between the technology life cycle of an R&D activity and its media exposure.

Scale of R&D Budgets

In general, financial resources (e.g., research budgets) are believed to play a key role in ensuring the success of R&D activities (Breschi & Malerba, 2011). Therefore, governmental organizations with limited resources strategically determine the scale of their R&D projects, and R&D entities are acutely aware of the importance of maintaining their relationships with policymakers (Besley & Nisbet, 2011) with decision-making powers.

The expenditure of public financial resources is a matter of great interest to the public, since budgets covered by taxes could be used for other social purposes (Stephan, 2012). Given this, both policymakers and R&D entities whose R&D projects are funded by governmental or quasi-governmental bodies are greatly concerned about the impact of their R&D programs. Accordingly, such R&D entities are motivated to justify R&D expenditures (Stephan, 2012).

Media exposure of R&D outcomes can help R&D entities justify their current or future R&D activities. Since policymakers are likely to establish policies in line with public opinion (Page & Shapiro, 1983), R&D entities are led to publicize their R&D outcomes. This way, they can steer public opinion and convince policymakers to make favorable decisions, especially regarding the evaluation of their current R&D activities as well as further R&D grants (Winter, 2004).

R&D entities' motivation to gain media exposure depends on the size of previously granted R&D budgets. Generally, the size of a project reflects its perceived importance (Payne, 1995). Accordingly, R&D entities that receive large-scale budgets face more pressure to justify the importance of their R&D activities and to meet the high expectations of governmental organizations and the public. Therefore, such R&D entities are more likely to seek media exposure of their R&D outcomes.

The same pattern can be found with gatekeepers. Large-scale budgets are invested in techno-scientific fields which are deemed strategically important. Therefore, they are under more intense public scrutiny. One of the key factors in news values (Blake & Haroldson, 1975), this prominence means gatekeepers are more likely to select related topics.

Hypothesis 3: There is a positive correlation between the scale of an R&D project budget and media exposure.

2.2.2. Impact of R&D Entities

Individual Reputation

As noted in a number of recent science and technology studies on intra-organizational or inter-organizational collaborative work, it is widely believed that effective utilization of scientific and technical human capital brings together professional network ties, technical skills, and resources (Bozeman, 2004), and thus leads to the production of supreme R&D results (Jones, Wuchty, & Uzzi, 2008). Since the reputation of an R&D entity (i.e., the prominence of researchers) plays an essential role in forming such human capital, researchers are motivated to build a good reputation in order to secure a successful partnership and to enhance the impact of their R&D activities.

The drive to build a good reputation is particularly strong among relatively low-profile, young researchers compared to senior researchers. Generally, other researchers' awareness of one's excellent R&D outcomes is crucial in establishing a good reputation. However, researchers with relatively little research experience would not have had time to accumulate enough excellent outcomes, not only because research productivity and impact tend to increase with age (Gonzalez-brambila & Veloso, 2007) but also because it takes time to build a good reputation. Moreover, those with little experience must rely on a smaller stock of scientific and technical human capital than senior researchers would.

Accordingly, young researchers would be more motivated to publicize their achievements via media exposure. Although researchers constantly monitor academic sources of information such as academic journals, it is difficult for them to grasp all current issues from these sources alone. Meanwhile, the media deliver simple yet insightful messages about science and technology, which provide many—including potential partners—with a helpful glimpse into R&D activities (Besley & Nisbet, 2011). Accordingly, as a complementary means, media exposure helps researchers draw the attention of potential partners; younger researchers wishing to strengthen their reputations would be more likely to publicize their R&D outcomes through the media.

Hypothesis 4: There is a negative correlation between the age of a researcher and media exposure.

Institutional Reputation

Today, higher education institutions fiercely compete with one another to recruit outstanding students and faculty and to secure external resources such as research grants (Stephan, 2012).[6] Currently, institutions place a great emphasis on marketing strategies for enhancing their brand images, especially in terms of earning greater prestige (Brewer, Gates, & Goldman, 2002; Kittle, 2000). A good image of an institution may attract outstanding students in the future, and its academic prestige may strengthen its faculty. In addition, an institution's excellent academic prestige may impress

[6] In fact, higher education institutions receive countless proposals from consultants who wish to assist in developing their brands. The image of such an institution is regarded as a critical differentiator in the marketplace (Frank, 2000).

potential partners, thereby helping its current researchers acquire further resources needed for R&D (e.g., networks, partnerships, and funds). Accordingly, universities are highly motivated to promote themselves through the media, making others aware of their activities via frequent media exposure and thus enhancing their brand values.

Universities can make strategic use of the media to publicize their R&D outcomes. The economic impact of a news article is nearly six times greater than a conventional advertisement of the same size (e.g., Bolland, 1989). Moreover, news articles on R&D outcomes are viewed as reports of facts rather than advertisements. This means they evoke public trust and help institutions build excellence in science and technology, which then ultimately improves their brand values. On the contrary, the public tend to accept only limited information from conventional advertisements since they are normally skeptical of the latent commercial purpose of advertisers (Soh, Reid, & King, 2007).

The attitudes of institutions vary according to their contextual positions. There is only little evidence of the various marketing strategies and tactics used by universities (Kirp, 2003). However, as evident in the commercial marketplace (Fornell, Robinson, & Wernerfelt, 1985), it can be argued that, in general, leading entities are able to build more positive reputations through higher awareness than those that fall behind. Therefore, the latter group would be motivated to put more effort and resources into promoting themselves. After all, only laborious efforts can bring about any change in awareness and preferences (Lieberman & Montgomery, 1988).

Hypothesis 5: There is a negative correlation between the renown of a research organization and media exposure.

3. DATA AND VARIABLES

3.1. Data Sources

We used project information data from the National Research Foundation of Korea (hereafter referred to as NRF), a primary funding agency that manages the majority of government research projects across all academic disciplines in Korea.[7] We obtained the records of performance and characteristics of all research projects launched in 2009 and 2010. In order to keep our focus on the nature of R&D at universities, we eliminated information about research projects performed by firms or government research institutes. Our data thus account for 3,070 research projects. University researchers must make annual reports of the outcomes of their projects funded by the NRF by entering their research results into the NRF's evaluation system. The evaluation of the reported outcomes may influence future research opportunities including grants.[8]

[7] As of 2012, the NRF manages 3.19 trillion KRW (approximately US$2.86 billion) of research funds per year.

[8] Researchers are required to report the grades of their previous government research projects.

Unlike survey data aimed at researchers or the public, our data include complementary information such as project-based R&D characteristics and performance, which enables us to demonstrate relevant theories and hypotheses. Moreover, the said data, which cover all disciplines, include most Korean universities undertaking R&D projects funded by the NRF. In short, our empirical evidence is more generalizable than data limited to one or a few institutions.

3.2. Variables

With regard to R&D projects, we calculate the counts of media exposure of R&D outcomes. As mentioned above, researchers who receive funding from the NRF are required to report the media exposure of their R&D outcomes. This information is then used by the NRF to approximate the social impact of each R&D project. Researchers must submit evidence of media exposure for inclusion in the NRF's project management database, such as links to relevant news article. Our dependent variable, Media_Exposure, is equal to the self-reported counts of media exposure of R&D outcomes (i.e., the number of news reports on R&D projects).

Based on the characteristics of R&D projects described in the database, we set three independent variables with regard to the impact of R&D activities. For technology readiness level, we use Tech_Readiness_Lvl, which indicates how close each R&D project is to being operational, as noted by Jeong, Choi, and Kim (2011). Each R&D project falls into one of the three categories: basic research, applied research, or development. We therefore set the corresponding values from 1 to 3. *Tech_Life_Cycle* denotes the target phase of an R&D project in the technology life cycle. According to Roussel, Saad, and Erickson (1991) specification of the technology life cycle, *Tech_Life_Cycle* is coded as a linearly increasing value by phase;1: "embryonic," 2: "growth," 3: "mature," and 4: "aging." *Project_Budget* indicates the natural logarithmic number of a project budget granted by the NRF in Korean won (KRW).[9]

We set two independent variables with regard to the impact of R&D entities. To measure individual motivation, we employ *Age*, the age of the principal investigator (PI) under the assumption that the team leader's individual motivation has a significant impact on the overall decision making process (Carmeli & Waldman, 2010). To measure institutional reputation, we classify universities into four levels, as in Jones et al. (2008) based on the scale of research grants each university received from the NRF in 2009 and 2010. A linearly coded variable, *School_Quarter*, indicates academic excellence. It reflects the reputation of each R&D entity.[10] *School_Quarter* is 1 if the R&D project team's university belongs to the upper quarter, 2 if it belongs to the second quarter, 3 if it belongs to the third quarter, and 4 if it belongs to the lower quarter.

[9] 1,000 KRW is worth approximately $0.90.

[10] The NRF publishes an official ranking of research institutes based on the research grants they receive, and the Ministry of Education, Science, and Technology calculates the amount of research grants to assess universities and reports these figures annually.

For techno-scientific outcomes, we employ two control variables which are major indicators of R&D outcomes; academic publications in peer-reviewed journals and patenting. Scientific_Impact reveals the accumulated impact of journals in which papers on R&D projects are published, and it could be used to address both quality and quantity of scientific discoveries by R&D projects. We set *Technological_Impact*, the number of patent applications resulting from R&D projects. This variable has often been used as the technological output of R&D projects in previous studies (e.g., Breschi & Malerba, 2011).

We introduce further control variables. First, we include a year dummy variable that indicates the year of a project's launch. It is important to remember that projects launched early enjoy more chances of publicizing their R&D outcomes that later ones. For an accurate analysis, R&D projects should be evaluated against and compared with those launched in the same year. We set Y2010, a dummy variable equal to 1 if the project was launched in 2010 and 0 otherwise (i.e., if the project was launched in 2009). We include controls for 18 different disciplines in accordance with the National Standard Science and Technology Classification in Korea, because the interests of the public vary by discipline (Nelkin, 1995). Therefore, they can potentially affect the likelihood of the R&D outcomes being reported to the public within the gatekeeping system for greater news values.

Table 1 summarizes the definitions of variables as follows:

TABLE 1. Definitions of Dependent and Independent Variables

Variable	Definition
Dependent variable	
Media_Exposure	The counts of media exposures of R&D outcomes
Independent variables	
Tech_Readiness_Lvl	Technology readiness level of the R&D project (1: basic research; 2: applied research; 3: experimental development)
Tech_Life_Cycle	The R&D project's phase in the technology life cycle (1: embryonic, 2: growth, 3: mature, 4: aging)
Project_Budget	The natural logarithmic number of the R&D project's research grant in KRW
Age	The age of the principal investigator (PI) of the R&D project
School_Quarter	Based on the sum of research grants received from 2009 to 2010, 1 if the R&D project team's university belongs to the upper quarter,2 if it belongs to the second quarter, 3 if it belongs to the third quarter and 4 if it belongs to the lower quarter
Controls	
Scientific_Impact	The accumulated impact of journals in which papers on the R&D project are published
Technological_Impact	The number of patent applications the R&D project generates
Y2010	Dummy equal to 1 if the project begins in 2010 and 0 otherwise
Disc_a	Dummy equal to 1 if the project discipline is mathematics and 0 otherwise
Disc_b	Dummy equal to 1 if the project's discipline is physics and 0 otherwise
Disc_c	Dummy equal to 1 if the project's discipline is chemistry and 0 otherwise
Disc_d	Dummy equal to 1 if the project's discipline is earth science and 0 otherwise

Disc_e	Dummy equal to 1 if the project's discipline is life science and 0 otherwise
Disc_f	Dummy equal to 1 if the project's discipline is agriculture and 0 otherwise
Disc_g	Dummy equal to 1 if the project's discipline is medical science and 0 otherwise
Disc_h	Dummy equal to 1 if the project's discipline is mechanics and 0 otherwise
Disc_i	Dummy equal to 1 if the project's discipline is material science and 0 otherwise
Disc_j	Dummy equal to 1 if the project's discipline is chemical engineering and 0 otherwise
Disc_k	Dummy equal to 1 if the project's discipline is electrical or electronic engineering and 0 otherwise
Disc_l	Dummy equal to 1 if the project's discipline is information and communications and 0 otherwise
Disc_m	Dummy equal to 1 if the project's discipline is mineral and energy resources engineering and 0 otherwise
Disc_n	Dummy equal to 1 if the project's discipline is nuclear engineering and 0 otherwise
Disc_o	Dummy equal to 1 if the project's discipline is environmental science and 0 otherwise
Disc_p	Dummy equal to 1 if the project's discipline is architecture, construction engineering or traffic engineering and 0 otherwise
Disc_q	Dummy equal to 1 if the project's discipline is neuroscience and 0 otherwise
Disc_z	Dummy equal to 1 if the project's discipline is liberal arts or social science and 0 otherwise

Table 2 illustrates the means, standard deviations, and minimum and maximum values of the independent and control variables. The average number of counts of media exposure is 0.195. In other words, on average, each research project publicize its results 0.195 times. Since the duration of each research project varies, this number is not a conclusive rate of media exposure. However, it implies that the counts of media exposure arezero-inflated.[11] In addition, the maximum value of *Tech_Life_Cycle* is 3, although we define it to be from 1 to 4. Few R&D projects aim to develop knowledge with relatively little potential to evolve. However, the mean (approximately 1.2) of *Tech_Life_Cycle* signifies that the majority of R&D activities are conducted in the relatively early stages of the technology life cycle.

TABLE 2. Descriptive Statistics

Variable	Mean	Std. Dev.	Min.	Max.
Media_Exposure	0.195	1.653	0	44
Tech_Readiness_Lvl	1.290	0.637	1	3
Tech_Life_Cycle	1.244	0.455	1	3
Project_Budget	18.091	0.664	15.425	21.129
Age	46.814	6.936	25	76
School_Quarter	1.269	0.567	1	4
Scientific_Impact	4.382	4.342	0	60.612
Technological_Impact	0.713	1.797	0	31

[11] In fact, we demonstrate whether Media_Exposure is zero-inflated through the Vuong test in Chapter 5 and find it zero-inflated. Thus, Chapter 4 explains a proper empirical model for zero-inflated data.

Y2010	0.261	0.439	0	1
Disc_a	0.023	0.151	0	1
Disc_b	0.092	0.288	0	1
Disc_c	0.087	0.282	0	1
Disc_d	0.008	0.090	0	1
Disc_e	0.155	0.362	0	1
Disc_f	0.024	0.152	0	1
Disc_g	0.125	0.330	0	1
Disc_h	0.068	0.252	0	1
Disc_i	0.056	0.229	0	1
Disc_j	0.046	0.209	0	1
Disc_k	0.078	0.268	0	1
Disc_l	0.125	0.331	0	1
Disc_m	0.028	0.165	0	1
Disc_n	0.020	0.138	0	1
Disc_o	0.014	0.118	0	1
Disc_p	0.023	0.150	0	1
Disc_q	0.015	0.122	0	1
Disc_z	0.013	0.113	0	1

4. METHODOLOGY

The Poisson regression model is a commonly used method for analyzing count data. However, many count outcomes do not follow the Poisson distribution as they have a variance larger than the mean–a condition called overdispersion[12]–or contain an excessive number of zeros.

Thus, when the outcome data Y are overdispersed, the negative binomial (NB) regression model, which follows the standard Poisson model specification but incorporates the overdispersion parameter α, is normally applied for modeling purposes. When the outcome data Y have an excessive number of zeros, the zero-inflated binary and count process models are applied, on the assumption that the excess zeros are generated by two separate processes.

The zero-inflated negative binomial (ZINB) regression model is a combination of two processes, the standard NB model and the binary model which is usually a logit model. In particular, the ZINB model is used when the outcome variable is a count variable with excessive zeros and a large vari-

[12] Overdispersion can cause excessively small standard errors of the estimated parameters due to the underestimation of the level of dispersion in the outcomes.

ance. Specifically, the zero response is associated with both a binary model and an NB model. Thus, the expected count is expressed as a combination of the two processes.

If *i* th observations in a random sample of *Y*, Y_i follow the ZINB distribution, then the probability of $Y_i = y_i$ is as follows: (1)

$$\Pr(Y_i = y_i) = \begin{cases} P_i + (1-P_i)\left(\dfrac{1}{1+\alpha\mu_i}\right)^{\alpha^{-1}} & if_i \quad y_i = 0 \\ (1-P_i)\dfrac{\Gamma(\alpha^{-1}+y_i)}{\Gamma(\alpha^{-1})\, y_i!}\left(\dfrac{\alpha\mu_i}{1+\alpha\mu_i}\right)^{y_i}\left(\dfrac{1}{1+\alpha\mu_i}\right)^{\alpha^{-1}} & if \quad y_i > 0 \end{cases} \quad (1)$$

X_i is a vector of covariates, while μ_i and p_i denote $\exp(X_i'\beta)$ and the probability of excess 0 respectively, α denotes the overdispersion parameter, and the mean and variance of the ZINB random variable are $(1-p_i)\mu_i$ and $(1-p_i)\mu_i\,(1+(\alpha+p_i)\mu_i)$ respectively. It is worth noting that the Vuong test (1989) can be used to compare the ZINB model with a standard NB regression model (Greene, 1994).

5. EMPIRICAL RESULTS

Table 3 shows the empirical estimation of our model. Firstly, to verify the robustness of our empirical model, we designed two specifications (i.e., Model 1 and Model 2) with different hypothesized contexts. Model 1 includes variables primarily related to the contents of news items. In other words, these variables are related to the characteristics of R&D activities and techno-scientific outcomes. On the other hand, in Model 2, variables related to the characteristics of R&D entities are added to the set of variables in Model 1. Furthermore, we set *Scientific_Impact* and *Technological_Impact* as inflated variables in both specifications because media exposure of R&D is made possible by the existence of R&D outcomes.

TABLE 3. Zero-inflated Negative Binomial Estimation Results

Variable		Model 1	Model 2
	Tech_Readiness_Lvl	-0.307 (1.20)	-0.069 (0.28)
	Tech_Life_Cycle	0.387 (1.17)	0.295 (0.92)
	Project_Budget	1.021*** (6.02)	1.077*** (6.29)
	Age		-0.050*** (2.73)

	School_Quarter		-0.529** (2.08)
	Y2010	-0.738** (2.25)	-0.659** (2.04)
	_cons	-20.373** (5.91)	-18.896*** (5.50)
	Discipline dummies	Yes	Yes
Inflate	*Scientific_Impact*	-0.168*** (3.66)	-0.162*** (3.54)
	Technological_Impact	-0.548*** (3.55)	-0.528*** (3.49)
	_cons	2.339*** (7.20)	2.276*** (6.90)
lnalpha	_cons	2.113*** (8.16)	2.035*** (7.62)
	Number of observations	3,070	3,070
	LR chi2(23)	68.66	81.70
	Prob > chi2	0.000	0.000
	Log likelihood	-742.011	-748.531
Vuong test	*Z*	3.46	3.59
	Pr > z	0.000	0.000

* $p < .1$, ** $p < .05$, *** $p < .01$

Note: Standard errors of each estimate are displayed in parentheses below each coefficient. Discipline Z is used as the baseline for discipline dummies

In both Models 1 and 2, the results of the Vuong test are significant at the 1% level, showing that it is more appropriate to use the ZINB model than the NB one. In addition, in α both models is also significant at the 1% level with positive coefficients, indicating that the ZINB model is more appropriate than the zero-inflated Poisson model for our analysis.

As for the variables related to our hypotheses, the estimates of the coefficients largely present strong consistency both in signs and significance levels between Models 1 and 2, which is indicative of the robustness of our empirical model. The estimated coefficients of *Project_Budget*, Y2010, *Scientific_Impact*, and *Technological_Impact*, as well as the constants (i.e., _cons) have the same signs and are satisfied at the same significance levels in both models, whereas those of *Tech_Readiness_Lvl* and *Tech_Life_Cycle* are not significant in either model.

Regarding the contexts for R&D activities, the positive signs of the coefficients of *Project_Budget*, which is significant at the 1% level in both Models 1 and 2, confirms Hypothesis 3. On the other hand, the results of the coefficients of *Tech_Readiness_Lvl* and *Tech_Life_Cycle*, which are not significant in either model, support neither Hypothesis 1 or 2. These results suggest that while concerns about reaching other R&D entities for collaboration or knowledge transfer do not exert much influence, concerns about the justification of R&D activities have a crucial impact. This contrast implies that researchers are concerned with sustaining their R&D activities per se but do not necessarily seek additional advantages from their R&D outcomes through media exposure (e.g., commercialization and techno-scientific hegemony).

As for R&D entities, the results of *Age* show that as the younger the researchers, the higher the probability of media exposure, which confirms Hypothesis 4. These results imply that unsurprisingly younger researchers are more eager to build good personal reputations, because they are in need of attaining more human capital or because they have fewer academic achievements, necessary for securing potential partners. The results of *School_Quarter* do not support Hypothesis 5. Rather, the opposite is observed between *School_Quarter* and *Media_Exposure* in Model 2. The coefficient of *School_Quarter* is significant at the 5% level with a negative sign. Interestingly, this result indicates that the higher the ranking of the R&D team's institution, the more frequent the media exposure is.

This tendency contrary to Hypothesis 5 can be explained at the organizational level. Generally, high ranking universities with better human resources (i.e., more high-quality researchers) conduct more R&D projects than those with lower rankings. Therefore, the public relations offices of high ranking universities might have contacted more journalists to publicize their R&D outcomes. This accumulated experience in networking with journalists may contribute to the diffusion of news items. After all, journalists focusing on science and technology tend to rely on institutional sources such as large research universities as well as informative materials such as journals (Logan, 1991). Thus, the number of information channels determines the impact of university rankings on media exposure, much more than the eagerness of each institute to publicize itself. Admittedly, this speculation remains to be proven through a meticulous examination.

The coefficients of *Scientific_Impact* and *Technological_Impact* are negatively significant at the 1% level in Models 1 and 2. The higher the values of *Scientific_Impact* and *Technological_Impact*, the less likely there will be a zero value of *Media_Exposure* (Cameron & Trivedi, 2009). These results suggest that the actual innovations in the science and technology community are usually conveyed to the media without major distortions. That is, media exposure corresponds to the values given by authorities in science and technology. The gatekeeping process ensures that high-impact news items have more chances of reaching the public than those with a low techno-scientific impact. In other words, R&D entities wishing to advertise their low-impact R&D outcomes via media exposure may not succeed.

The coefficients of Y2010 are significant at the 5% level with negative signs in both Models 1 and 2. R&D projects launched early are likely to have more information exposed through the media than those launched later, provided that other conditions such as R&D outcomes and the age of the PI are the same. Therefore, we can infer that techno-scientific information probably spreads more widely with time: journalist and other media professionals are led to value and become interested in the outcomes of previously reported R&D projects, which means the chances of further media exposure are higher for innovations already exposed in the media. Since the maximum difference in the start dates of the R&D projects compared in our study is only one year, it is too early to generalize the relationship between time and media exposure of R&D outcomes—we cannot judge whether the said difference is due to the characteristics of the year or duration of news exposure. It is an issue that calls for more thorough reasoning and further demonstrations such as a time series analysis.

6. CONCLUSION

Using a nationwide novel dataset to analyze the characteristics and performance of R&D entities and their projects, this study empirically demonstrates factors determining the media exposure of R&D outcomes. To conclude, our empirical results prove that the scale of an R&D project positively affects the counts of media exposure of its outcomes, whereas the level of technology readiness and the technology life cycle exert no significant influence. In addition, it could be deduced that young researchers are more likely to publicize their R&D outcomes than senior ones and that R&D outcomes from high-ranking universities are more likely to be publicized than those from low-ranking universities. Finally, the results empirically show that the greater the number of R&D outcomes, the more likely they are to be publicized through the media.

The aforementioned results present policymakers with some practical implications. Firstly, in promoting the diffusion of science and technology, especially to the public, policymakers should consider possible incentives for information providers (i.e., researchers and public information officers). The social need for a diffusion of techno-scientific innovations to the public (e.g., technology transfer) is an insignificant factor in media exposure, whereas personal benefits and other sensitive issues related to a researcher's own R&D activities (e.g., justification for R&D activities) drive researchers to publicize their R&D outcomes. Therefore, policymakers, especially those wishing to achieve a better diffusion of scientific and technological innovations, must establish an effective system of incentives which will encourage researchers to publicize their R&D outcomes for the benefit of society. Secondly, rather than simply calculating the counts of media exposure, policymakers should consult complementary references to evaluate the social impact of R&D outcomes in their evaluation of R&D projects. Arguably, maximizing the social impact of R&D outcomes is one of the achievements that should be considered in the overall evaluation. Moreover, media exposure is certainly affected by a number of conditions beyond researchers' control, such as university rankings. Accordingly, rather than relying solely on the records of media exposure, policymakers can better ascertain the awareness and impact of specific topics in science and technology by using additional sources (e.g., expert peer reviews and opinion surveys aimed at the industry and public) that offer more objective perspectives. Moreover, if necessary, developing a standard index to combine evaluation results from diverse additional sources may help policymakers measure and understand the actual social impact of R&D outcomes.

Our study has certain limitations. The novel and unique dataset used in this study presents a limited view: it covers only the media exposure of R&D outcomes funded by the government. News items on techno-scientific innovations include both recent R&D outcomes from universities and those from government research institutes and firms. Accordingly, because organizational contexts vary across different sectors, our analysis of the contexts and their impact on the media exposure of R&D outcomes may not be applied to different types of organizations. In addition, a large number of news reports on science and technology mainly focus on scientific/technological conflicts such as nuclear-related issues and research ethics (McComas & Simone, 2003). Therefore, our study is limited to the nature of universities and their R&D activities.

Furthermore, our study does not thoroughly investigate the actual impact of the news media on the public. Each form of the news media has a distinct degree of impact. For example, the influence of TV news is greater than that of newspapers, and even then, TV stations differ in their impact given their various tones and audience ratings (Chaffee & Kanihan, 1997). Furthermore, news audiences do not fully trust or understand every message about science and technology from the press (Roberts, Reid, Schroeder, & Norris, 2011); audiences accept information selectively. However, our study assumes the impact of all news items to be equal. Therefore the results cannot be used to elucidate the actual social impact of R&D outcomes through the news media.

This study proposes certain directions for future research. Although we present hypotheses about the process of media exposure in light of the unique characteristics of techno-scientific innovations, more in-depth tracking of information transferred from researchers to the press at each level of the process of media exposure may help us understand not only some of the distinct perceptions about innovations but also the strategic purpose of organizations and individuals. In addition, further studies on extensive issues are required, which explore controversial and negative topics in science and technology as well as the promotion of R&D outcomes. Finally, a detailed study of the social mechanism of forming public opinion, especially within the academic society, and how it affects the actual policymaking process may enhance our understanding of the nature of media exposure of R&D outcomes.

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