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Receiving information at Korean and Taiwanese universities, industry, and GRIs

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Abstract This article examines the incentive structure underlying information transfers received by the three key players of the Triple Helix paradigm: universities, industry, and government research institutes (GRIs). For Korea and Taiwan, which are the cases under analysis here, such an empirical examination has not yet been conducted on a quantitative level. Using a unique dataset of survey responses from a maximum of 325 researchers based in Korean and Taiwanese universities, industry, and GRIs, this article shows that there are some significant differences between and within countries. Most importantly, policy interventions to promote university-industry-GRI interactions impact the degree to which specific information transfers are considered useful. In Korea, formal transfers are emphasized, while both formal and, in particular, informal transfers are emphasized in Taiwan.

Keywords R&D collaboration · Information flows · Triple helix relations · Information transfer · East Asian developmental state · Technology spillovers

MSL Classification 91F99 · 62P20 · 62P25 · 62J05 · 62J10

JEL Classification O31 · O32 · O33 · O34 · O39

Introduction

This article examines survey responses of researchers engaged in R&D collaboration based in Korean and Taiwanese universities, industry, and government research institutes (GRIs) to understand how and why research-related information is received. I look particularly at research sector, research goals, and university–industry–GRI (UIG)

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collaborative research instigation. Each of these has been discussed in the existing literature on R&D collaboration, but they are integrated here for a more complete understanding of each country's national innovation system (NIS) and, more importantly, the nature of Triple Helix (i.e., UIG) relations in these two countries, where funding is increasingly being provided to generate unique and commercializable research results through UIG R&D collaborations. If we assume that there is a greater propensity for information diffusion to occur when universities and GRIs collaborate with firms rather than when firms collaborate with each other,[1] UIG R&D-promoting policies offer a significant, positive externality.

The Triple Helix concept, presented in its initial and more developed forms in Etzkowitz (2000, 2003, 2008) and Leydesdorff (2006), has prompted a flurry of empirical work on the East Asian region. This article builds on these earlier studies, some of which have focused expressly on R&D collaboration in Korea (Kim and Park 2008), on the importance of research hubs in Taiwan (Hu 2011), or on cross-country comparisons (Park et al. 2005). Emphasized here, however, is the role of government programs which promote Triple Helix relations. Rather than follow the accepted convention and assess government-funded programs through research output, though, the dependent variable in this article is the utility of information received through a number of transmission vehicles. This is particularly salient for a discussion of scientometric indicators, as patenting and publication output are often a function of successfully receiving information. This is certainly the case for bibliometric studies which examine collaboration through citation of publications (Rinia et al. 2002; Zhang et al. 2009).

There are a number of viable reasons for UIG R&D collaboration to occur on its own (David et al. 2000; Scott et al. 2001; OECD 2004), but the science and technology (S&T)-oriented policymaker is all too often forced to create R&D collaboration targets to respond to what can ultimately be described as market failures in R&D. To correct for such failures in a general sense, the government identifies and funds projects that tend to be privately unprofitable but socially beneficial, such as government funding which has been found to typically target research efforts which cross between universities and industry (Manjarres-Henriquez et al. 2008). In this light, one measure of social benefit is the degree of spillovers accompanying these projects (Stiglitz and Wallsten 1999). This is particularly important for this article, as the examination is focused expressly on government funding programs which promote UIG R&D collaboration.

This article is structured to address the aforementioned topics in several sections. First, an examination is conducted of the channels through which information is received and how certain channels have the potential to impact R&D output. I build on previous models of information transfer, namely Jaffe (1998), before turning to the specifics of government R&D funding upon information transfers in the Korean and Taiwanese cases. Despite the shared developmental trajectories of these two countries, cross-country comparisons are essential to fully understand the impact on the utility of information flows by research sector, research goal, and publicly instigated collaborative research. That defines the structure of the third section, which outlines the nature of the unique dataset and the methods through which it will be analyzed. The results are presented in the fourth section, and the fifth section concludes with policy evaluations for both countries and a call for further research on information transfers.

[1] This was proposed originally by Dasgupta and Maskin (1987).

Government intervention and information transfers

A sizable literature explicitly addresses the issue of information transfers. They have been used as output measures (D'Aspremont and Jacquemin 1988), as a positive function of R&D productivity (Griliches 1998), or as a negative function of costs (Bernstein and Nadiri 1988). In these studies, however, the precise source and nature of such transfers is neglected. This could be due to the strict focus these studies place on the private research sector, where knowledge transfers might levy significant costs to the research-engaging firm, making appropriability issues paramount.

This highlights our underlying goal: understanding the incentives surrounding information transfers. For industry, crowding-out is the primary issue, as government intervention through technology policy is meant to create an environment which encourages private investment rather than substituting for it (Branscomb and Keller 1998). Government funding for universities and GRIs has been identified as having the potential to alter the course of innovation (Nelson and Rosenberg 1993) with potentially significant impacts on our well-being (Stiglitz and Jayadev 2010), which is clearly true for the Korean and Taiwanese cases, as I will show in the following section.

There are a number of instances in which government intervention has facilitated information transfers through UIG R&D collaboration. The nature of the collaboration is hardly uniform, however. In some cases, such as Semiconductor Manufacturing Technology (SEMATECH), increased competitiveness is the ultimate goal; in others, the government facilitates the partnering of private firms with GRIs (Roos et al. 1998).[2] The government is also able to coordinate UIG R&D collaboration with the intention of overhauling an entire industry, which was intended through the Lean Aircraft Initiative (LAI).[3] As well, small, university-based research centers, such as the U.S. Industry–University Cooperative Research Centers (IUCRC), are designed to facilitate academic-to-firm information transfers. Indeed, IUCRCs have been shown to play a role in the uni-directional form of information transfer, namely via faculty consultation, co-authoring of publications, and the hiring of graduate students (Adams et al. 2001).

The cases: Korea and Taiwan

When examining information transfers in East Asia, we would be negligent to overlook the role of public policies. Models of government involvement in Korea and Taiwan are generally structured along two foci (Evans 1998). The market-friendly model is aligned with the World Bank's (1993) seminal text which describes how East Asian governments managed to maintain macroeconomic essentials throughout the rapid growth period. On the other hand, the industrial policy model of Johnson (1982) and subsequent analyses (Amsden 1989; Wade 1990) describe the entrepreneurial function of government policies, in addition to the macroeconomic stability of the market-friendly model. Policymakers, thus, are responsible for identifying potentially strong and/or weak sectors and distributing

[2] SEMATECH targeted the increased competitiveness of US chip manufacturers, and the hands-off approach of the government enables SEMATECH participants to effectively manage the R&D consortia. PNGV was designed to improve national competitiveness in manufacturing through innovations which would achieve three times the fuel efficiency of 1994 family sedans (Roos et al. 1998).

[3] Now the Lean Aerospace Initiative.

funding to maximize growth prospects.[4] The distinction between these two models and the present reality of R&D in Korea and Taiwan is that policymakers target the skills and effort of research fund recipients. The state is not always effective in this regard (Breznitz 2005), so the subsequent analysis will speak to the successes and failures of such funding.

Nevertheless, both Korea and Taiwan's policymaking structures are designed to bolster their NIS, with particular emphasis on UIG R&D collaboration. This represents a marked difference from what some have described as diverging economic policies in the two countries.[5] While the details of the NIS-bolstering policy structures are not offered here,[6] it should be noted that, from the early 1980s, the Taiwanese government withdrew from direct intervention while supporting efforts to build a knowledge foundation as a particular development policy (Hsueh et al. 2001). This relative lack of overall funding in R&D in Taiwan has created an environment in which R&D fund recipients use disbursements more productively and with more determination. GRIs in both countries have played a key role over time (Lee 2000; Berger and Lester 2005), but the relative lack of funding in Taiwan could explain why GRIs continue to be very important in Taiwan (Hu and Mathews 2009). Underlying these efforts, though, is the utility of information transmission vehicles.

Modeling information transfers

This article contextualizes the benefit of information transfers through R&D returns and applies a similar structure to that used in Jaffe's (1998) study of the U.S. Advanced Technology Program (ATP).[7] Jaffe's underlying premise is that market, knowledge, and network spillovers increase social returns, ultimately measured here as the sum of private returns and the benefits from spillovers.[8] This is also consistent with the literature which identifies social welfare as a positive function of information transfers between research collaborators (Hagedoorn et al. 2000) or that some sort of connection among UIG can lead to an even greater distribution of knowledge (Cassiman et al. 2008).

In Jaffe's model, knowledge is assumed to originate in universities, industry, or GRIs and is transferred to other research entities through publications or patents, indicated by χ_1 in Fig. 1. One research entity's efforts to create returns, in the form of reputation effects (A_1) for universities and GRIS or profits (A_2) for industry, can generate additional returns through other research entities' reputation effects (D_1) or profits (D_2), or ultimately benefit the customer (E) through some measure of increased satisfaction. Both public and private research entities can generate income through patent licensing (B), determined in part by a

[4] Evans (1998) actually outlines three models. The entrepreneurial function of the second model embodies the investment concerns of the third model, we believe.

[5] For example, unlike the Korean case, Taiwan's economic plans in the past have no implementation procedures, are not supported by controls, and lack credibility (Hamilton and Biggart 1988). As well, others subscribe to the view that Korea is "interventionist" while Taiwan is "supportive" (Park 1990). Specifically, there is evidence in Korea of domestic market protection and industrial targeting; in Taiwan, medium-term economic plans limit policymakers authority to allocate credit (Park 1990).

[6] See Shapiro (2007) for historical accounts.

[7] The ATP, incidentally, is the basis for several of the research funding programs in Korea and Taiwan from which the unique dataset of this paper is drawn.

[8] Knowledge spillovers occur through reverse engineering or through the reading of other's findings in published form, and full compensation is not awarded to the original source of such information. Market spillovers benefit the customer when the same price is paid for products of higher quality, which are the result of product innovations. As well, process innovations can lead to decreased production costs which result in lower prices, again benefiting the consumer. Network spillovers are exemplified by the successful coordination between research entities to create a new technology.

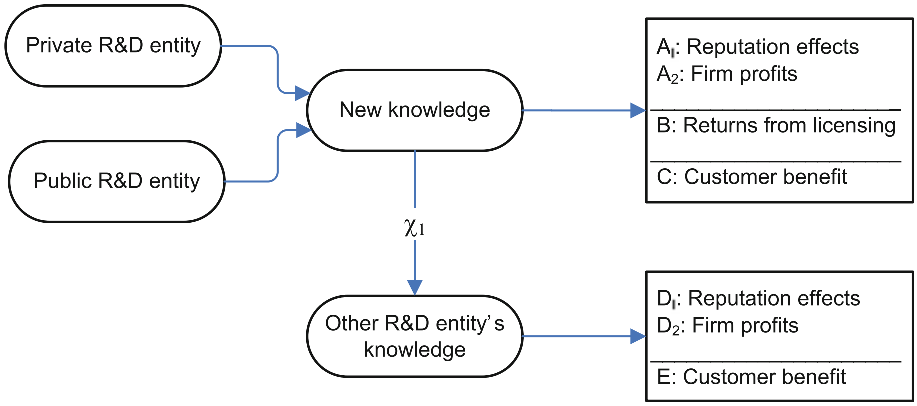

Fig. 1 Returns to R&D and information channels without collaboration

functioning technology transfer office or office of technology licensing. In summation, Fig. 1 describes how a research entity's attempts to create private returns (the sum of A_1, A_2, or B) leads to greater social returns (the sum of A_1, A_2, B, C, D, and E.), when information transfers along χ_1.

Under the assumption that greater information transfers lead to increased returns, both social and private, the framework presented in Fig. 1 makes a strong case for the government to prioritize and support projects which result in high levels of information transfers. This theoretical structure is ill-equipped, however, to deal with the specifics of information transfers within a UIG R&D collaborative framework. In addition, only three forms of information transfer are considered by Jaffe: patents, publications, and licenses. If we acknowledge that information can be transferred between universities, industry, and GRIs on additional levels—with significant consequences—Jaffe's (1998) structure must be modified.

I look to Hall et al.'s (2000) examination of the relations between universities and firms in the ATP Program and Adams et al.'s (2001) analysis of the U.S. IUCRCs for additional examples of information transmission vehicles. The latter, in particular, shows that knowledge transfers are increasing, particularly through faculty consultations, co-authorship of publications across sectors, and the hiring of former graduate students. These transfers are unidirectional, though, focusing strictly on information flows received by industry. This has been the conventional approach (see Joly and Mangamatin (1996), for example), despite the calls for examination of the bi-directionality and non-linearity of information transfers (Mowery et al. 2004).

We are in alignment with those who identify a more complex arrangement of inter-organizational R&D based on the character of relationships between universities and/or GRIs and private firms (Fontana et al. 2003). There are, for example, numerous meetings before beginning the actual R&D process, not to mention the updates and modifications done during the actual research. This effectively invalidates the linearity assumption of one-way information flows, especially when commercializable research results are pursued and the universities and GRIs incorporate the market-oriented research of industry.

Under these assumption of bi-directionality, a more appropriate reflection of private and social returns to R&D and information channels in the context of UIG R&D collaboration

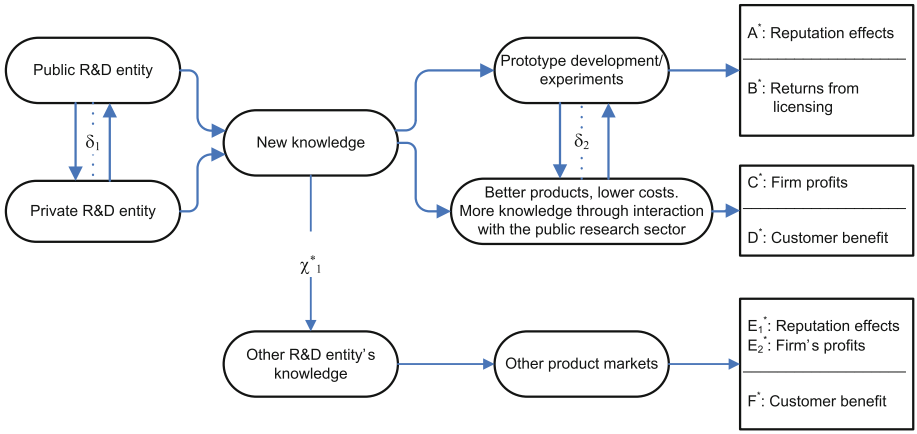

Fig. 2 Returns to R&D and information channels with UIG collaboration

is presented in Fig. 2, building on Jaffe's (1998) model. This figure captures the UIG information transfers at several different levels, based on the assumption that ideas do not necessarily originate in one sector or the other (Fontana et al. 2003). The initial stage of UIG R&D collaboration, represented by δ_1 in Fig. 2, involves the bi-directional sharing of ideas about commercialization and project feasibility. Information transfers along δ_1 occur through conferences/meetings as well as dialogue about each collaborator's previous research results. Also included in δ_1 is previously documented research in the form of patents and publications. After the goals are determined, each sector works to complete their specified tasks: public research entities develop prototypes or conduct experiments and tests while the private sector prepares its manufacturing facilities for new production. Throughout this period, research entities from the public and private sector may be in consultation, in conference, and exchanging researchers. The information transfers occurring at this stage of the project are represented as δ_2 in Fig. 2. Finally, information transfers via χ_1^* in Fig. 2 are distinct from those of χ_1 in Fig. 1 in that the former arises from UIG R&D collaboration while the latter does not.

Method and data

To properly understand the role of information transfers in the context of UIG and the Triple Helix paradigm, we must examine how they are predicted by research sector, research goals, and university–industry–GRI (UIG) collaborative research instigation. The focus on research sector allows us to examine differences in how information transmission vehicles are viewed given a variety of research specializations. In many ways this is an exploratory analysis, as the research sector-information transfers connection has yet to be established. Yet, it also provides the first, greatly needed step in understanding how Korea and Taiwan differ with regard to the following sectors: chemical manufacturing, plastic and rubber manufacturing, non-metal minerals manufacturing, primary metal manufacturing, fabricated metals manufacturing, machinery manufacturing, computer and electronics manufacturing, electrical equipment manufacturing, transportation equipment manufacturing, and all other sectors.

The second step looks particularly at the goals outlined on the right-hand side of Fig. 2. Again, this is to provide a clear picture of which research pursuits are a function of utility in information transmission vehicles, and differences will be identified between countries and between universities, industry, and GRIs. If information transfers are a positive externality of government-led efforts to foster UIG interactions, this analysis will speak to which type(s) of research orientation are more (and less) ideal public funding recipients than others. The following categories are how R&D success is defined: patenting output, publishing output, both patenting and publishing, and other definitions of R&D success.

Finally, this article looks expressly at the impact of public fund-instigated collaborative R&D on the utility of information transmission vehicles. If cross-section R&D collaboration were only accomplished through Triple Helix-related policies, including this as an explanatory variable would bias the results, but such collaboration occurs under a variety of conditions, including but not limited to instances of public fund instigation. Given the aforementioned literature review, we would expect Taiwan to show significantly higher impacts, as public funding is relatively less available. Given the lack of research on this particular topic, however, it is difficult to make clear predictions. What will be made apparent is the presence or absence of market failure-correcting efforts by the government.

Measuring information transfers

As Fig. 2 shows, there is no single mechanism to account for policy-led information transfers, although there have been attempts to quantify output from such efforts. David and Foray (1996), for example, make a solid effort to isolate the "knowledge distribution power" of an innovation system, which includes institutions supporting information transfer (e.g., the norm of disclosure), incentives toward codification, and an intellectual property rights regime which facilitates disclosure. In any case, the selection of information transfers considered here is based on first-hand interviews between the author and research directors and managers in Korea and Taiwan. The selection has also been influenced by a number of studies which, while provocative, are limited in their focus on a linear, university-to-firm transfer of information, particularly Rahm et al. (1999), Cohen et al. (2002), Lécuyer (1998), and Scott et al. (2001).

It is necessary to acknowledge the number of potential problems arising when measuring information transfer. Simply put, the mechanisms through which knowledge flows are absorbed by firms are not always directly and objectively observable (Han 2001). As well, first-hand interviews and quantitative analysis of the unique dataset questionnaire responses confirm that information transfers are not uniform but complementary. This was expected, given Cohen et al.'s (1998) factor analysis and subsequent conclusion that channels of information flow tend to be used together when they are at least moderately important. Cohen et al. found specifically that person-to-person interactions are complements with other forms of information flow, such as publications and conferences. Yet, hires, joint ventures between industry and universities, patents and contract research are less important. This is reconfirmed in Fritsch and Schwirten (1999), Breschi and Catalini (2010), and Cohen et al. (2002), the latter of which indicates that public and personal channels of information transfer—publication, conferences, and informal interactions—are more important than licenses and cooperative ventures.[9] It is on the basis of the pre-

[9] These studies, again, are minimized to the uni-directional transfer of information from the university to the firm.

existing literature that I use these directly observed constructs. The exact questions on which these constructs are based can be found in the Appendix.

Data collection

Empirical estimates are based on data collected from a closed-ended survey questionnaire distributed to public and private research directors who received public funding for cross-sector R&D collaboration. A single time period is considered: 2005. This unique database adheres to the sampling methods of Sakakibara (1994), Branstetter and Sakakibara (1997), and the bulk of quantitative studies surveyed in Ruegg and Feller (2003), all of which focus on specific government research funding programs.[10]

White papers, formal directives, and personal interviews with analysts at government agencies in both countries led to the selection of several funding programs which call for UIG R&D collaboration as a stressed or necessary condition of receiving research funds. In Korea, KOSEF's (of MOST) Centers of Excellence Program (CoE) and IITA's (of MIC) Information Technology Research Center (ITRC) Program provide funding to university-based researchers. The Taiwanese counterpart to university-based programs is the TDP's Technology Development Program for Academia (TDPA). GRI-based project leaders were selected from Korea's Electronics and Telecommunications Research Institute (ETRI) and Taiwan's Industrial Technology Research Institute (ITRI). Representing private sector participants in UIG R&D collaboration are participants in Korea's Mid-term Technology Development Program and Communal Core Technology Development Program (ITEP, for short; both of the Ministry of Commerce, Industry, and Energy [MOCIE]) and Taiwan's Small Business and Innovation Research (SBIR) Program (of MOEA).

In Korea, sources of government funds for UIG R&D collaboration include, but are not limited to, MOST, MOCIE, and the Ministry of Information and Communication (MIC). These three ministries are representative of much of the federal obligation for R&D, and the conditions of its provision affect the structure of UIG R&D collaboration. In the case of MOCIE and MIC, funds are provided for R&D on the condition that results are commercialized. MOST, with its stronger emphasis on basic research, orients its programs around research results with both long-term and commercializable prospects. In any case, the provision of funds to public institutes is conditioned by the stipulation that relations with industry are fostered.

These relations between the funding ministry and the research entities of interest are illustrated for Korea in Fig. 3, and for Taiwan in Fig. 4. The most apparent distinction is that private firms are given a much greater opportunity in Taiwan to receive funding in terms of its source, although the data confirms that the quantity of R&D is much less than in the Korean case (OECD 2006). The SBIR Program, which is the source of the private firm respondents in the dataset, is but one component of such public funding.[11]

KOSEF outlined the policy orientation of the CoE over fifteen years ago, but there is evidence of programs renewing the call for cross-sector R&D collaboration, such as MIC's "839" policy. This policy changes the focus of public research institutes from basic

[10] This dataset was collected in the winter and spring of 2005–2006, following field research and interviews by the author with public and private research directors in Korea (summer 2005) and Taiwan (winter 2005).

[11] Another source of funding are the increasingly popular university-based and GRI-based incubation centers. Despite their phenomena-like status, these SMEs and start-ups were not targeted in the survey for fear that they were not necessarily engaging in cross-sector R&D collaboration or lacked sufficient expertise.

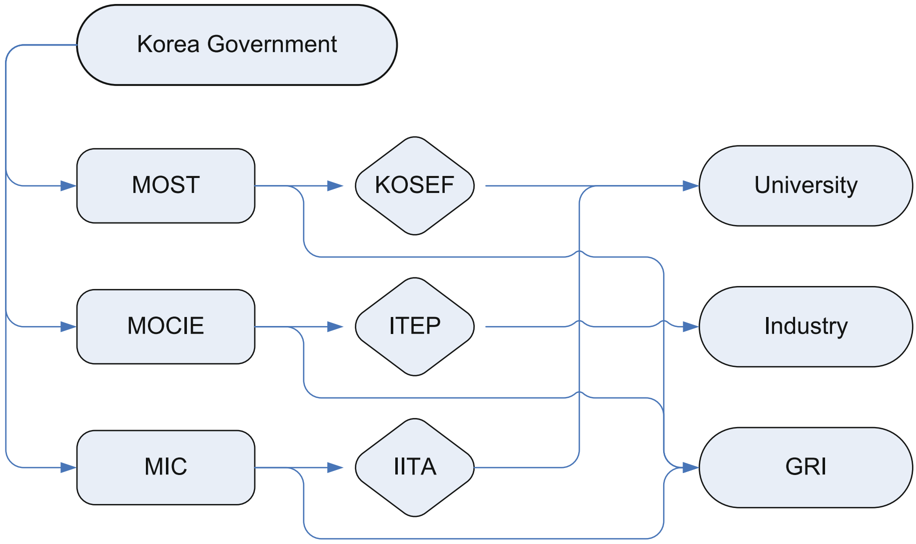

Fig. 3 Korea: connections between ministries and research entities

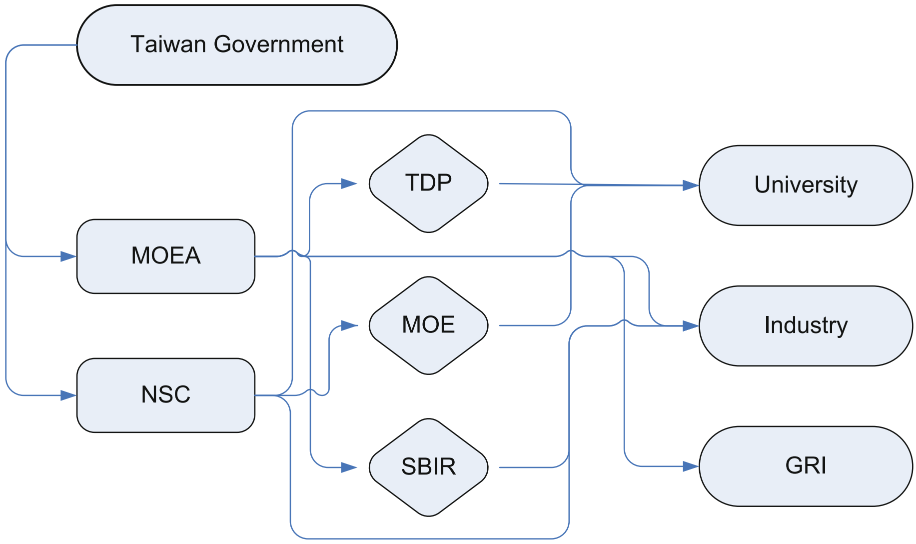

Fig. 4 Taiwan: connections between ministries and research entities

research to research that will enlarge the market for particular products. Applied and developmental research is the focus, and UIG R&D collaboration has been identified as a necessary means.

In terms of bureaucratic organization, despite fluctuations over time between these two countries, the centralized government in Korea has resulted in a shift of policymaking from the bureaucracy to the president's office, while technological oversight diminished. At the

Table 1 Survey response rate information

	Distributed	Completed	Response rate
Taiwan			
ITRI	74	46	0.62
TDPA	79	18	0.23
SBIR	363	119	0.33
Overall (Taiwan)			0.39
Korea			
ETRI	99	49	0.49
CoE	66	24	0.36
ITRC	43	27	0.63
ITEP	118	42	0.36
Overall (Korea)			0.46

same time, leaders from industry are now involved on the National Science and Technology Council, which is responsible for S&T policies and government R&D funding. Similarly, industry is also involved in the management of GRIs by participating on the relevant research council boards.[12] In Taiwan, the organizational structure has been considerably looser but coordinating mechanisms still play a role (Cheng et al. 1998),[13] particularly to promote collaboration between GRIs and SMEs, rather than with large, successful firms. The science advisor within the government is responsible for making the relevant R&D-related decisions, and there is also a council which is accountable to the president and produces proposals to foster innovation and growth. Members of this council include the president of the National Science Council (NSC), Academia Sinica, foreign research entities with particular expertise, and the GRI president.

In all, the dataset is based on a maximum of 325 questionnaire responses from research project leaders and research institute directors, all of whom are recipients of public research funds in one of the aforementioned programs. The overall response rate is 43 percent, described in detail in Table 1. As the sample is not randomly generated, the response rate may appear problematic, but the selection issue is not as serious as it might look. Indeed, the omission of these potential respondents is expected to create an even more impressive selection of participants in UIG R&D collaboration.

Respondents determined their qualifications based on the questionnaire's cover page instructions and requirements, specifically that s/he must be a project leader or a research center director. Since the TDPA, SBIR, CoE, ITRC, and ITEP programs have all experienced large increases in participation in the years immediately preceding the questionnaire distribution, it is quite likely that many non-respondents self-determined that they lacked sufficient relevant experience and hence chose not to complete the questionnaire. A similar rationale can be applied to ITRI and ETRI, where internal restructuring occurred immediately following the first-stage field research. To some degree, this represents shortcomings in questionnaire distribution methods and the inaccessibility to classified program-level data to target the best available list of research entities engaging in UIG R&D collaboration. But, it was ultimately decided that it would be preferable that the

[12] Cited from www.oecd.org/dataoecd/30/60/34242958.pdf.

[13] Cheng et al. (1998) list the following coordinating mechanisms: U.S. aid, the strong central bank, and a number of organizing structures and bodies peripheral but connected to the government.

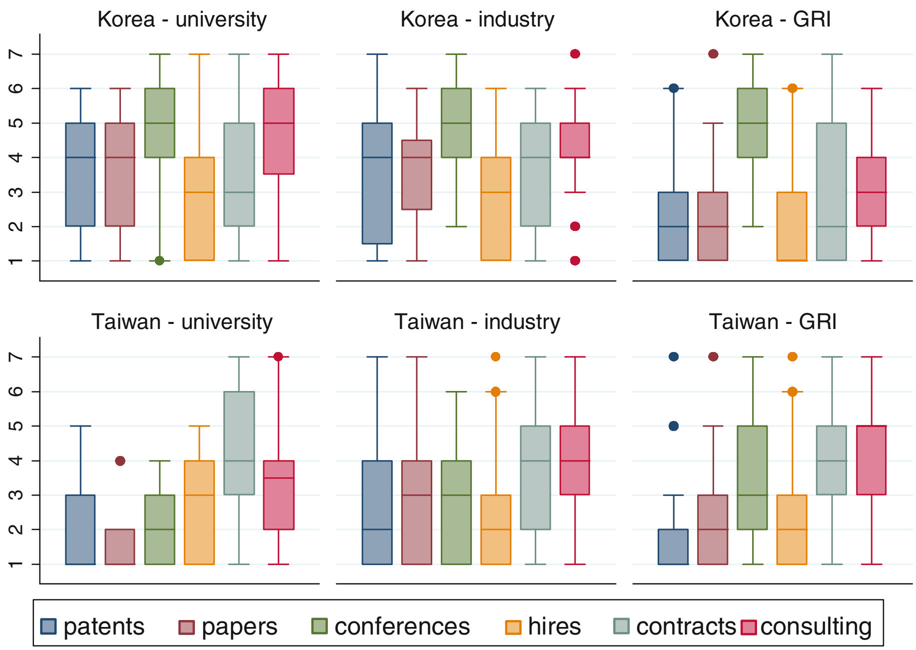

Fig. 5 *Box–whisker* plot across countries and UIG categories

research entities be given the opportunity to self-select their involvement. This was also in the interest of preserving an environment of anonymity.[14]

There are additional reasons for believing that the non-response problem is less serious than it might appear. First, the number of distributed questionnaires is an over-estimate, representing the maximum number of respondents available as of the final drafting of the questionnaire, based on the available information on each program and research institute. Second, some project managers and directors would not have been able to respond due to the fact that they were no longer available. They may have left the GRI or lost their government funding.[15] In some respects, confidentiality issues limited access to specific, historical information about individual institutes and firms. This was particularly true with regard to industry-based programs, SBIR and ITEP.

Finally, with regard to the university-based research centers – TDPA, CoE, and ITRC – each government program allocates a portion of its overall funding to more basic research efforts. This is consistent with the U.S., Japanese, and European counterparts to the Korean and Taiwanese R&D funding programs which emphasize university-firm R&D collaboration. Basic research is distinct from applied research and experimental development, and typically occurs at the university rather than the GRI or private firm.[16] Among the TDPA, CoE, and ITRC funding recipients, those who engage in basic research will experience

[14] The questionnaire was distributed and collected by the author, ministry-level officials, GRI-based directors, and government agency officials.

[15] This is, again, tied to limits of the available information.

[16] When firms are large enough, they will often possess the infrastructure and capabilities to engage in basic R&D, but these large enterprises are not considered samples in the dataset, and there will be no discussion of their impact and influence.

little or no cross-sector R&D collaboration, and therefore may well have not self-determined that it would not be appropriate for them to response to the survey.

Results

Scores for six information transmission vehicles are based on a 7-point Likert scale, 7 being greatest, for how much useful information is received from the private (or public) sector in 2005: patenting, publications, hires, conferences, contract research, and consultations. At a descriptive level, the box-whisker plot in Fig. 5 shows that information is reported as useful on a nearly identical level across Korean universities and industry. At the same time, GRIs in both Korea and Taiwan receive information in a similar pattern, with conferences representing the dominant vehicle of receiving information.[17]

In line with Aldrich and Nelson (1984), Amemiya (1985), and McKelvey and Zavoina (1975), I use ordered probit to first determine cross country differences as well as differences among universities, industry, and GRIs. For each of the six information transmission vehicles, ordered probit regressions using aggregated data across both countries show that Korea and Taiwan are significantly different for all but information transfers via hires and consultation.[18] Nonetheless, the data were separated according to country, and ordered probit regressions were done again for each of the six transmission vehicles on a UIG categorical variable and dummies for each research sector. To determine statistically significant differences among universities, industry, and GRIs, three sets of two sample *t*-tests (i.e., tests for whether universities are equal to industry, whether industry is equal to GRIs, and whether GRIs are equal to universities), the results of which are not presented here, were done for each of the six transmission vehicles.

Tables 2 and 3 present the bulk of these statistical results. First, in rows 2, 3, and 4, marginal changes for universities, industry, and GRIs are presented. These are the predicted probabilities of a maximum increase (to 7 on the Likert scale) for each type of information transmission vehicle, holding all other variables in the model at their means. I have opted to present these measures rather than coefficients for the ordered probit regression, because marginal changes are more readily comparable and interpreted.

In Korea, with regard to comparisons between the receipt of information for universities, industry, and GRIs, t-tests (not presented here) reveal no differences among the three groups for information received via conferences and contracts, based on the models of Table 2. The remaining transmission types, however, show statistically significant differences on a number of levels. Shown in the third column of Table 2, for information received via patents in Korea, the predicted probability of universities was significantly less than both industry and GRIs. For publications, hires, and consultation, the probability of an increase in information received for GRIs was significantly greater than those of universities and industry.

[17] The rectangular boxes in each figure represent those responses between the twenty-fifth percentile (lower hinge) and the seventy-fifth percentile (upper hinge). The median is found directly in the middle of the box. Lines (or "whiskers") extending from the box are capped with adjacent values, beyond which are outside values, represented by small circles. Adjacent values are calculated by multiplying the interquartile range (the difference between the first and third quartile values) by 1.5, and adding or subtracting it from the upper or lower hinges, respectively.

[18] A Taiwan (i.e., country) dummy was used. Additional details about right-hand side variables in this preliminary test of country differences include the following: sector dummies were included, and a three-level categorical variable was included to test for differences across universities, industry, and GRIs.

Table 2 Korea: ordered probit coefficients (sector) and marginal changes (UIG)

	Total	Patents	Papers	Conf.	Hires	Contracts	Consult
The following three rows represent marginal changes							
University	0.001	0.118***	0.105***	0.006	0.295***	0.234***	0.024*
	(0.002)	(0.042)	(0.038)	(0.007)	(0.068)	(0.061)	(0.014)
Industry	0.003	0.260***	0.101**	0.006	0.264***	0.209***	0.043*
	(0.004)	(0.076)	(0.042)	(0.008)	(0.073)	(0.066)	(0.023)
GRI	0.014	0.367***	0.333***	0.005	0.551***	0.269***	0.131***
	(0.014)	(0.073)	(0.068)	(0.006)	(0.076)	(0.062)	(0.046)
The following ten rows present coefficients from ordered probit model							
Chem.	0.615*	1.121***	0.299	0.586*	−0.198	0.032	0.579*
	(0.332)	(0.349)	(0.337)	(0.337)	(0.349)	(0.337)	(0.337)
Plastic & rubber	0.773*	1.102**	0.384	0.366	0.340	0.267	0.592
	(0.438)	(0.460)	(0.445)	(0.444)	(0.450)	(0.439)	(0.445)
Non-metal	–	–	–	–	–	–	–
Metal	–	–	–	–	–	–	–
Fabric. metals	−0.428	0.720	−0.362	0.337	−0.964	−1.029	−0.458
	(0.784)	(0.797)	(0.795)	(0.792)	(0.881)	(0.875)	(0.827)
Mach.	−0.48	0.373	−0.011	0.145	−0.998**	−0.315	0.131
	(0.413)	(0.439)	(0.420)	(0.409)	(0.496)	(0.431)	(0.415)
Comp. & electronics	0.248	−0.257	0.172	0.401	0.112	0.094	0.530**
	(0.266)	(0.280)	(0.271)	(0.268)	(0.291)	(0.272)	(0.268)
Electrical	0.188	−0.043	−0.269	0.398*	0.122	0.265	0.258
	(0.244)	(0.258)	(0.251)	(0.247)	(0.265)	(0.248)	(0.246)
Transport	−0.204	−0.871	−0.755	−0.199	0.147	0.426	0.327
	(0.586)	(0.660)	(0.609)	(0.586)	(0.656)	(0.607)	(0.594)
Other	0.492	0.371	0.211	0.638*	0.310	−0.020	0.869***
	(0.331)	(0.339)	(0.335)	(0.333)	(0.346)	(0.338)	(0.333)
N	120	123	123	125	122	122	124
Pseudo *R*2	0.03	0.11	0.06	0.01	0.04	0.01	0.05
χ^2	25.15***	48.96***	26.17***	8.08	17.24*	5.12	25.67***

Note: *, **, *** denote $P < 0.10$, 0.05, and 0.01, respectively. Standard errors are in parentheses

In Taiwan, on the other hand, the marginal changes based on the ordered probit regression results, presented in Table 3, rows 2, 3, and 4, reveal strong overlaps among universities, industry, and GRIs. Two-sample t-tests show no statistically significant differences among the UIG categories for information transferred via patents, hires, contracts, and consultations. In sharp contrast to Korea, when there are significant differences between the three groups it is universities that have the highest predicted probability: greater than industry for transfers via publications; greater than both industry and GRIs for transfers via conferences.

The bottom sections of Tables 2 and 3 (rows 5 to 13) present the coefficients from the ordered probit model to determine which sectors utilize particular information transmission vehicles. In Korea (Table 2), respondents in certain research sectors increase one's position in certain types of information transfers by increasing the *z* score values (or by increasing the standard deviations), all else being equal. For the utility of information that is received

Table 3 Taiwan: ordered probit coefficients (sector) and marginal changes (UIG)

	Total	Patents	Papers	Conf.	Hires	Contracts	Consult
The following three rows represent marginal changes							
Univ.	0.063	0.660*	0.669***	0.608***	0.334**	0.120	0.135*
	(0.054)	(0.370)	(0.143)	(0.147)	(0.140)	(0.077)	(0.077)
Industry	0.035**	0.447	0.348***	0.227***	0.455***	0.160***	0.079***
	(0.015)	(0.371)	(0.045)	(0.039)	(0.048)	(0.032)	(0.022)
GRI	0.028*	0.586	0.445***	0.106***	0.387***	0.112***	0.060*
	(0.016)	(0.370)	(0.073)	(0.035)	(0.073)	(0.036)	(0.024)
The following ten rows present coefficients from ordered probit model							
Chem.	0.468*	0.132	−0.006	0.948***	0.367	0.399*	0.322
	(0.259)	(0.254)	(0.255)	(0.244)	(0.268)	(0.235)	(0.238)
Plastic & rubber	0.049	0.249	−0.058	−0.027	−0.282	0.255	0.517
	(0.351)	(0.330)	(0.353)	(0.338)	(0.399)	(0.321)	(0.330)
Non-metal	0.863	−4.814	0.237	1.714*	0.392	0.965	1.362
	(1.019)	(149.913)	(1.029)	(1.036)	(1.029)	(1.029)	(1.034)
Metal	0.242	0.386	−0.015	0.192	−0.674	0.379	0.740
	(0.605)	(0.608)	(0.647)	(0.635)	(0.757)	(0.610)	(0.609)
Fabric. metals	1.267**	0.027	0.491	0.543	1.004*	1.654***	1.466***
	(0.529)	(0.569)	(0.539)	(0.545)	(0.546)	(0.555)	(0.553)
Mach.	0.488*	0.218	0.123	0.436	0.729**	0.246	0.474*
	(0.273)	(0.292)	(0.271)	(0.274)	(0.291)	(0.274)	(0.264)
Comp. & electronics	0.085	−0.287	−0.388*	0.113	0.238	0.271	0.034
	(0.217)	(0.233)	(0.222)	(0.217)	(0.235)	(0.211)	(0.204)
Electrical	0.244	0.085	0.210	0.457**	−0.013	0.083	0.258
	(0.221)	(0.239)	(0.233)	(0.228)	(0.237)	(0.224)	(0.215)
Transport	−0.402	−0.824	−0.328	0.619	−0.440	−0.608	−0.900
	(0.728)	(0.790)	(0.672)	(0.627)	(0.829)	(0.656)	(0.647)
Other	−0.099	−0.313	−0.115	0.214	0.117	0.178	−0.232
	(0.280)	(0.305)	(0.288)	(0.272)	(0.293)	(0.274)	(0.260)
N	143	161	158	157	150	159	161
Pseudo *R*2	0.01	0.02	0.02	0.05	0.02	0.02	0.03
χ^2	12.47	13.76	13.63	29.87***	12.59	14.87	20.64*

Note: *, **, *** denote $P < 0.10$, 0.05, and 0.01, respectively. Standard errors are in parentheses

via patents, this is particularly true for the fields of chemical manufacturing and plastic/rubber manufacturing. For the utility of information received via publications and contracts, no clear predictions can be made. Being based in either the chemical manufacturing or electrical equipment sectors increases one's position in information transfers via conferences 0.586 and 0.398 standard deviations, respectively. Information received via consultation is increased for respondents in chemical manufacturing and computer and electronics product manufacturing.

It is worth noting that in only one case is there a clear indication that the utility of information is not increased via a particular transmission vehicle. Indeed, the decrease by 0.998 standard deviations of information received by hires for the machinery

Table 4 Korea: marginal changes (goals) based on ordered probit regressions

	Total	Patents	Papers	Conf.	Hires	Contracts	Consult
Patenting	0.004	0.175***	0.146***	0.007	0.371***	0.236***	0.069**
	(0.005)	(0.046)	(0.041)	(0.007)	(0.062)	(0.052)	(0.027)
Publishing	0.011	0.540***	0.105*	0.002	0.425***	0.398***	0.113*
	(0.014)	(0.141)	(0.063)	(0.003)	(0.135)	(0.134)	(0.068)
Both	0.004	0.254***	0.243***	0.006	0.471***	0.185**	0.051*
	(0.005)	(0.091)	(0.086)	(0.007)	(0.112)	(0.073)	(0.031)
Other	0.004	0.265***	0.197***	0.007	0.314***	0.219***	0.032*
	(0.004)	(0.071)	(0.058)	(0.008)	(0.076)	(0.063)	(0.017)

Note: *, **, *** denote $P < 0.10$, 0.05, and 0.01, respectively. Standard errors are in parentheses. Coefficients and/or marginal changes for UIG and industry dummies are not reported

manufacturing sector may even be interpreted as a reversal of information received; there is lost utility via information flows is lost as fresh hires replace seasoned workers.

With regard to sectoral differences in Taiwan, shown in Table 3, there is also evidence of increases in certain types of information transfers by increasing the *z* score values (or by increasing the standard deviations), all else being equal. The utility of information that is received via conferences, for example, is increased for the chemical manufacturing, the non-metal minerals, and electrical equipment fields. For the fields of fabricated metals and machinery manufacturing, the utility of information is reported at a significant level via hires. It is also at a significant level for the chemical manufacturing and fabricated metals fields via contracts, and for the fabricated metals and machinery manufacturing fields via consultation.

This paints a picture where plastic and rubber manufacturing, computer and electronics product manufacturing, and transportation equipment manufacturing all report negligible amounts of utility of information received. In fact, for the computer and electronics field, there was a statistically significant decrease by 0.388 standard deviations of information received by publications. As was the case for the machinery manufacturing sector in Korea, this may be interpreted as a reversal of information received; information is lost as researchers in the computer and electronics field share their research via publications.

Turning now to the impact of how goals are defined, Tables 4 and 5 present the predicted probabilities of a maximum increase (to 7 on the Likert scale) for each type of information transmission vehicle, holding all other variables in the model at their means.[19] For those respondents in Korea that consider publishing as a research goal, presented in Table 4, the probabilities are on the whole greater than those respondents who consider patenting or both patenting and publishing to be a goal. This pattern if also present in the Taiwanese case, presented in Table 5, where the predicted probabilities for respondents with publishing as a goal increase the reported utility of information received via patents, publications, conferences, and hires. The exceptions are information received via contracts and consultation. While these results for Korea and Taiwan do not overlap perfectly, the subtle overlaps described above reveal that information transfers are particularly important for the publishing group.

[19] The model on which these measures are based includes UIG, country, and research sector dummies. Coefficients and/or marginal effects for these are not included in Tables 4 and 5.

Table 5 Taiwan: marginal changes (goals) based on ordered probit regressions

	Total	Patents	Papers	Conf.	Hires	Contracts	Consult
Patenting	0.025*	0.420	0.378***	0.173***	0.380***	0.131***	0.088***
	(0.014)	(0.311)	(0.064)	(0.044)	(0.064)	(0.037)	(0.029)
Publishing	0.092	0.914***	0.620***	0.393**	0.539**	0.089	0.083
	(0.081)	(0.158)	(0.199)	(0.168)	(0.217)	(0.068)	(0.060)
Both	0.040	0.560*	0.466***	0.259***	0.421***	0.192***	0.073**
	(0.025)	(0.325)	(0.099)	(0.081)	(0.101)	(0.067)	(0.035)
Other	0.033**	0.487	0.365***	0.199***	0.459***	0.146***	0.069***
	(0.016)	(0.315)	(0.052)	(0.042)	(0.056)	(0.035)	(0.023)

Note: *, **, *** denote $P < 0.10$, 0.05, and 0.01, respectively. Standard errors are in parentheses. Coefficients and/or marginal changes for UIG and industry dummies are not reported

Table 6 Ordered probit coefficients (public fund-instigated R&D collaboration)

	Total	Patents	Papers	Conf.	Hires	Contracts	Consult
Korea							
Public fund instigated	0.165***	0.061	0.013	0.097	0.098	0.274***	0.070
	(0.063)	(0.065)	(0.063)	(0.061)	(0.069)	(0.068)	(0.062)
N	120	123	123	125	122	122	124
Pseudo $R2$	0.04	0.11	0.05	0.02	0.04	0.04	0.05
χ^2	31.57***	49.69***	23.81***	10.60	17.00*	21.15**	26.58***
Taiwan							
Public fund instigated	0.187***	0.058	0.150***	0.166***	0.065	0.121***	0.091**
	(0.048)	(0.046)	(0.048)	(0.046)	(0.050)	(0.044)	(0.044)
N	143	161	158	157	150	159	161
Pseudo $R2$	0.02	0.02	0.03	0.07	0.02	0.03	0.04
χ^2	27.67***	11.79	18.29	41.61***	13.25	21.74**	24.68**

Note: *, **, *** denote $P < 0.10$, 0.05, and 0.01, respectively. Standard errors are in parentheses. Coefficients and/or marginal changes for UIG and industry dummies are not reported

We finally turn to the results of ordered probit regressions of the information transmission vehicles on the tendency for public funding to instigate UIG relations. Table 6 shows, by country, for each response on a 7-point Likert scale the ordered probit coefficients for public fund instigation.[20] There are some clear points of divergences between Korea and Taiwan. In Korea, presented in row 2, there is a clear disconnect between public funding which specifically targets UIG interactions and the utility of most of the information transmission vehicles discussed here. While it is encouraging to see that the aggregated measure (row 2) is statistically significant and positive, this can be attributed to the strong weight (in the aggregated measure) of information transfers via contracts. Given the complexities described in Jaffe's updated model and shown in Fig. 2 above, these

[20] The model on which these measures are based includes UIG, country, and research sector dummies. Coefficients and/or marginal effects for these are not included in Table 6.

results indicate lost opportunities for knowledge spillover. At the same time, the Korean results show that S&T policy targets are based less on informal interactions and more on formal R&D cooperative structures such as contracts. This is, simply put, the culture of Triple Helix interactions in Korea.

In Taiwan, the situation is quite different, with increased utility for all but two information transmission vehicles, specifically patents and hires. Among the statically significant results (excluding those of the aggregated information transfer measure in column 2), the ordered probit coefficients for conferences and publications, 0.166 and 0.150, respectively, are larger than those for the more formal vehicles of information transfer such as contracts and consultation. This provides additional evidence that the utility of informal mechanisms is more strongly predicted by public funding in Taiwan vis-à-vis Korea. At the very least, the results presented in Table 6 show much more balance between informal and formal transmission vehicles in Taiwan.

Conclusions

This article has attempted to address an apparent lacuna in studies of the Triple Helix in Korea and Taiwan: the incentive structures for UIG interactions. The structure of interest is utility of information transferred between universities, industry, and GRIs, as such information has the potential to boost knowledge spillovers and increase R&D output. This, in line with Jaffe (1998; Fig. 1 above) and the updated model (Fig. 2), contributes to private and social returns to R&D. Returns such as these are assumed to remain undeveloped without some form of policy intervention. For this reason, I have put special emphasis on how public funds instigate R&D collaboration.

Through an analysis of a unique dataset of researchers based in Korean and Taiwanese universities, industry, and GRIs, exploratory research is quite revealing, specifically differences between countries in general, between research sectors within each country, and among universities, industry, and GRIs within each country. Across six different information transmission vehicles, GRIs claim a higher utility in general than either universities or industry; there is much more balance among the three groups in Taiwan; where there are differences, universities tend to claim a higher utility. On the whole, what we learn from these findings is that GRIs are the greatest facilitator of Triple Helix (i.e., UIG) interactions, providing further evidence in support of Hu and Mathews (2009).

There is no clear pattern of differences between the two countries with regard to which research sectors are receiving the greatest utility across the six information transmission vehicles. What is apparent is that chemical manufacturing is the research sector which finds utility across a number of information transmission vehicles in both Korea and Taiwan. In Korea only, plastic and rubber manufacturing finds utility in a couple of information transfer types. In Taiwan, on the other hand, the fabricated metals manufacturing and the machinery manufacturing research sectors are the sectors which identify utility in a number of information transmission vehicles. What we can conclude from these findings is that sector-specific studies of UIG relations, particularly those which place any emphasis at all on knowledge spillovers and information transfers, must account for information transmission vehicle type. It also indicates the need for closer examination of particular research sectors within each country, particularly research which applies a sector-specific case study approach. In this way, this article is limited in its ability to provide a clear understanding of sector-specific workings with regard to information transfers.

The two countries diverge also in one final, important way, providing an addendum to the incentive-related literature of David et al. (2000), Scott et al. (2001), and OECD (2004). Results from ordered probit regressions reveal that public fund-instigated R&D collaboration increases with the utility of formal transfers of information in Korea, while both formal and informal transfers have these effects in Taiwan. In fact, informal transfers of information seem to be more strongly predicted in Taiwan. In the context of the theoretical model presented in Fig. 2, we can conclude that Taiwan's broader coverage of the utility of information types produces greater social returns to R&D than in Korea. Thus, while the state is not always effective in targeting research fund recipients (Breznitz 2005), Taiwan is more effective than Korea. Nonetheless, future research opportunities must continue to focus on the distinction between research output achieved through formal transfers and informal transfers. This will advance the policy-related discussion and support additional tests of the updated Jaffe (1998) model.

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Appendix

Information transfers construct:

[*On questionnaires for respondents at GRIs and universities*] To what extent does useful information move from private firms to your institute?

[*On questionnaires for respondents at private firms*] To what extent does useful information move from public institutes to your firm?

Please answer for the following methods.

(1 = no movement at all; 7 = a lot of movement)

Patents	1	2	3	4	5	6	7
Publications	1	2	3	4	5	6	7
Meetings or conferences	1	2	3	4	5	6	7
Hires	1	2	3	4	5	6	7
Contract research	1	2	3	4	5	6	7
Consulting	1	2	3	4	5	6	7

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