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The Triple Helix paradigm in Korea: A test for new forms of capital

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Abstract

The Triple Helix paradigm – a construct addressing the research-based links between government, universities, and firms – is lacking in formal tests. This study attempts to alleviate this deficiency by conducting an empirical analysis of the effects of relationship-based forms of capital, which has been identified by theorists as an attribute of Triple Helix-based R&D. OLS results utilising a unique dataset (KORTAI R&D) comprised of 108 questionnaire responses of Korean directors and project leaders reveal that new forms of capital are especially significant for firms and universities while less so for government research institutes (GRIs). The effects for universities, however, are delayed and indicate a spillover effect.

Keywords

Triple Helix
Korea
public–private
R&D
collaboration
university
GRI

Introduction

The Triple Helix paradigm has not been extensively applied to the Korean case as persuasive studies of R&D in Korea have traditionally been conducted in terms of the National Innovation System approach.[1] While both methods provide important perspectives of how R&D is conducted, the Triple Helix model presents a particular emphasis on public–private R&D collaboration. This form of collaboration has become increasingly necessary in Korea, given the complexity of new technologies. Such advancements typically require interdisciplinary skills, large financial investments, testing, and experimental and production facilities (Yusuf 2003).

This paper considers whether key aspects of the Triple Helix model are true for the Korean case, offering lessons for other countries approaching a similar level of technological capacity. This is, thus, a call to move beyond an understanding of Korea's industrial success based on underlying, nation-level differences, as (Westphal 1990) states, and address more recent policies promulgating a Triple Helix structure. Specifically, to what extent does the Triple Helix structure generate new forms of capital in Korea? If capital does increase as an externality of public–private R&D collaboration, there are obvious implications for policymakers, who are responsible for maximising social returns to R&D.

Theoretical and empirical contributions are offered here, while responding to the general research question. Theoretically, the linkages between the government, universities, and private firms offer little in terms

1 See Kim (1993) for an excellent example.

of differences between subgroups. Subgroup refers here to the different types of research entities within the public and private research sectors. The private sector, for example, is comprised of a range of different sized firms, each providing unique qualities to the Triple Helix dynamic. Further, when standard Triple Helix linkages are drawn between universities, firms, and the government, government research institutes (GRIs) are not concretely positioned in the schematic. If knowledge creation occurs in the context of a fluid and evolving community and formal organisations are poor methods for learning, Powell et al. (1996) are correct in identifying sources of innovation where firms, universities and GRIs intersect. To test for this, GRIs must be explicitly included in the Triple Helix paradigm.

Methodologically, Triple Helix studies are typically conducted at the case study level, and comparative research is not abundant. This paper offers alternatives to these conventions, based on the contention that a number of stylised facts are ripe for quantitative analysis. Using a subset of the unique KORTAI R&D dataset, in combination with interview results between the author and research directors in Korea, this paper offers a response to a number of program-, sector- and country-level questions, which are often raised on a case-by-case basis. With appropriate techniques and a sufficient sample size, generalisations can be tested with confidence. The context of such tests involves instances of public–private R&D collaboration resulting from a specific policy structure, which targets innovations with long-term potential and commercialisability. In this regard, the Korean case is particularly interesting, given changes in S&T related institutions in support of the Triple Helix paradigm. Interaction and collaboration between the public and private research sectors is now a stated policy goal. The mechanisms utilised for this effect include the continued use of government funding and R&D subsidisation, as well as reinforced targeting of joint R&D, shared research facilities, more effective tax incentivisation and a bolstered IPR regime (Chung 2004).

The structure of this paper is designed to present a full analysis of the Korean case, test the aforesaid aspects of the Triple Helix paradigm, and make propositions about the viability of transference of best-practice techniques to developing countries. To that effect, the next section briefly reviews the literature and presents background details on the Korean case. The third section introduces the research questions and the relevant variables from the KORTAI R&D dataset. Summary statistics are also presented in this section to validate a number of key assumptions. Section four outlines the empirical specification, providing the rationale for the use of an ordinary least squares (OLS) model. The fourth section also presents the results from this model and a number of immediate interpretations. The fifth section concludes this discussion by reinforcing the value of the Korean case.

Literature review and case description

When considered as a whole, the literature conveying the Triple Helix phenomenon is substantial. A thematic breakdown by country, method, or theory, however, reveals paucity in the existing research. Here, we draw attention to the micro-level institutions at work with respect to the Korean case.

Empirical studies on the subject of micro-level institutions related to the Triple Helix paradigm are neither in great supply nor representative of developing nations. Further, a survey of this literature reveals an overall absence of simultaneous assessments of both the public and private research sectors. There is also an overwhelming focus on the European phenomenon, recently presented in an analysis of increased entrepreneurship at a single Belgian university (Van Looy et al. 2006) and in an earlier study of diffusion through an analysis of technology transfer offices at German universities (Kruecken 2003). Colombo and Delmastro (2002) generate micro-level data in a comparison of firms located in Italian science parks, and Schartinger et al. (2002) also gathered micro-level data for their study of the complexity of knowledge interactions between Austrian universities and firms. The data of these last two studies is similar in nature to the content of the KORTAI R&D dataset, which is used here (and discussed at length below). Marques et al. (2006) also provide valuable insights with their case study of a Portuguese university's effectiveness in promoting innovation and entrepreneurship throughout the local area.

Beyond Europe, the focus turns to Latin America and East Asia, with few exceptions. These studies also fail to simultaneously consider multiple components of the Triple Helix paradigm, but they do provide deep insight into the particulars of individual countries. For example, Casas et al. (2000) show how the presence of key scientific and engineering fields in Mexico's Bajio region exhibit relationships along the lines of the Triple Helix model. Mirroring the aforementioned Portuguese university case study, Bernasconi (2005) emphasises the absence of the Triple Helix paradigm in a case study of Chile's Pontificia Universidad Catolica, detailing the transition from a teaching to a research orientation, in spite of shortages in government funding. The value of these developing country-based studies has led to explicit calls in support of the Triple Helix paradigm, such as Saad and Zawdie's (2005) detailed progression of Algeria's post-independence industrialisation. This is echoed by Etzkowitz and Leydesdorff (2000), who survey related events in Europe, Latin America, and Asia, particularly the government's involvement in altering the relationship between knowledge producers and users.

Turning now to the relevant case-specific literature, Korea is typically presented comparatively with other countries having Triple Helix qualities. Park et al. (2005) compare Korea and the Netherlands based on 'knowledge infrastructure'. They conclude that Korea's scientific and technological output is greater than that of the Netherlands, measured by webometric, scientometric and technometric indicators, but offer little in terms of policy prescription. Etzkowitz and Brisolla (1999) also study Korea comparatively, using Korea with Brazil as proxies for the entire region. The authors ultimately make a connection between technology-bolstering policies and the international political economy, concluding that intervention in technology policies is no guarantee of success.

This discussion extends the aforementioned micro-institution-based literature with a largely unexplored aspect of the Triple Helix paradigm, all the while focusing on the Korean case. This untested hypothesis is presented by Etzkowitz (2003), who claims that new social arrangements and channels of interaction are needed if industry and government are joined by universities in knowledge-based economies. Earlier studies allude to this (Faulkner and Senker 1994), concluding that cooperation between universities and private firms is based on personal contact.[2] Others have found that interactions between university and firm researchers occur through a dense network of interpersonal relationships (Dierdonck et al. 1990),[3] while still others have determined that the source of innovation-based relationships is captured through the personal contacts of research institution employees (Fritsch and Schwirten 1999). The task here, thus, is to sufficiently operationalise these new forms of capital.

Korea's institutional background provides an ideal opportunity to test for relationship-based capital. The Triple Helix in Korea is rooted in the 1960s and 1970s, when imitation was the source of rapid industrialisation. This imitation, or 'reverse engineering', of existing foreign technologies required minimal investment in R&D for the production of simple products. However, reverse engineering rarely occurs in a vacuum, requiring multi-level interactions among firms, universities, and public R&D institutes (Kim and Nelson 2000), and the Korea Institute of Science and Technology (KIST) was established in 1966 as Korea's first GRI in response. KIST's specific purpose was to provide solutions for less complicated technological issues as well as to help internalise foreign technologies. As the industrial focus expanded and the demand for technical support increased in the 1970s, KIST was spun-off into various specialised institutes, such as the Electronics and Telecommunications Research Institute, which is the GRI of focus in the subsequent analysis.

The development of private firms' in-house research capabilities diminished the need for GRIs, and they were restructured in 1982 as part of the Ministry of Science and Technology's (MOST) National R&D Programme. GRIs now complemented industry research by engaging in upstream tasks, thereby preventing the weakening of the science knowledge base and duplication of efforts. The National R&D Programme was the first indication that policy directives acknowledged the significance of moving beyond simple imitation or reverse engineering of foreign-based technologies. It also reflected the government's involvement in promoting upstream research at GRIs rather than at universities. Compared with their foreign counterparts, Korean universities play a much smaller role in national R&D efforts, which some attribute to the prevalence of instruction over research (Chung 2001).

From the mid-1980s, the Korean government began technology planning and evaluation of public R&D programmes, to minimise duplication

2 For Faulkner and Senker (1994), this contact is a function of scientific publications.

3 These findings are particular to the Belgian case.

of research efforts and delineate R&D specialisations between different ministries. This attempt to develop a long-term, strategic approach to R&D called for the participation of both the public and private research sectors. All research interests were given consideration, ultimately leading to the first concrete cases of publicly instigated public–private R&D collaboration (Chung 2001). Public–private R&D collaboration increased in frequency from 1989 as the government implemented programmes modelled on the United States. Small Business Innovation Research (SBIR) programme and the Advanced Technology Programme (ATP). Korean counterparts for the SBIR and ATP programmes are the bases for the private and university sub-groups of the Korean data (from the KORTAI R&D dataset).

The New Economic Five Year Plan of 1993 was the first set of policies clarifying the government's role in the transfer of technology from the public to the private research sectors (Choi and Lee 2000). The Plan aimed to facilitate collaboration among research entities from both sectors, and it was followed by the 1995 Support Act for Starting SMEs, which facilitated technology transfer specifically from the public to the private sector. The financial crisis of 1997–98 prompted a marked shift in Korea's policy orientation to address some of these alignments, particularly the 21st Century Frontier Technology R&D Programme. With goals of raising the degree and number of researchers and reforming Korean universities, the effects upon public–private R&D collaboration will have continued significance, reflected partially in the nature of the specific research programmes considered here.

Research questions and data

A test of Etzkowitz's (2003) claims is inherently bound to a number of related research questions with direct consequences for our understanding of the Triple Helix structure. In this way, the conclusions offered here are much richer than a straightforward analysis of relationship-based capital in Korean public–private R&D collaboration. These additional issues include the importance of recognising sub-groups of the public and private research sectors and the need to differentiate between new capital and pre-existing capital. We specifically examine the effects of new relationship-based capital upon research project success. It is expected that success is positively affected by collaboration with previous partners, in line with Etzkowitz's (2003) description of the Triple Helix paradigm.

Private sector sub-grouping is divided between small and medium enterprises (SMEs) and large firms. Ernst (2000) notes that the chaebol-dominant industry structure in Korea was accompanied through 'octopus-like diversification' into many unrelated industries. Such over-diversification minimised specialisation, which some claim actually hindered the accumulation of knowledge (Ernst 2000). As such, SMEs are now viewed as the vehicle through which ideas and technologies germinate. The focus in technologically advanced countries is more R&D concentration in start-ups, incubators and SMEs. Some of these small companies will become absorbed in larger companies after launching new innovations. Others, however, may attempt to upgrade their results, enter the export market and expand (Yusuf 2003). This point is still valid, despite patenting advantages of large firms, such as economies of scale and scope and complementarities and spillovers between departments (Cohen and Levin 1989).

Growth in the research efforts of SMEs may have been the effect of a structural change. Kim (2001) identifies the Asian crisis of 1997 as a factor in the growth of SME innovation in Korea. The chaebols reduced R&D investment following the crisis, prompting an SME-based upsurge. The number of venture firms in Korea also increased from 100 (pre-crisis) to more than 7,000 in June 2000, as a result of post-crisis layoffs by the chaebols. This growth in SMEs and new start-ups is also affected by the targeting of public funds, either by using the new technology as bank loan collateral, subsidising R&D personnel, or providing technical information and services (Chung 2004).

Universities and GRIs are often held apart based on the supposition that universities focus on basic research while GRIs are more applied-oriented, although OECD (2002) classifies them both under the heading of basic research. There is also the difference in tasks and focus, primarily universities focus on both research and education, while GRIs are solely concerned with research. Neither these differences nor their potential impact is denied, but we do consider whether GRIs and universities are treated similarly.

In the case of technologically leading countries, such as Germany and the United States, basic research is undertaken generally at the higher education level. Japan is the exception and resembles the Korean case because of the high degree of investment in (total) R&D by private firms. Andersson and Dahlman (2001) point out that Korean universities do not specialise in basic research. This just as well since public funding for universities is low compared with GRIs, forcing universities to seek out funding from private enterprises. This, Andersson and Dahlman conclude, may help to shift university research away from knowledge base-enhancing efforts.

A number of funding programmes have been designed in part to continue exchanges between the public and private research sectors. To limit bias in the KORTAI R&D dataset, a selection of these funding programmes is given focus here. White papers, formal directives, and personal interviews with analysts at government agencies indicate that such funding programmes share a common characteristic in that public–private R&D collaboration is considered a necessary condition for receiving research funds. The public sector sample is based on the Korea Science and Engineering Foundation's (KOSEF) Centres of Excellence (CoE) Programme and the Institute of Information Technology Assessment's (IITA) Information Technology Research Centre (ITRC) Programme. These two programmes provide funding to university-based research centres. Also included in the public sample are GRI-based project leaders from ETRI, Korea's largest GRI. The private sector sample is drawn from participants in the Mid-term Technology Development Programme (ITEP, for short).

Questionnaires for the KORTAI R&D dataset were distributed to test, for a number of phenomena present, the effects of social arrangements and channels of interaction in public–private R&D collaboration. Several examples of relevant survey-based research are presently available, including that of Mansfield (1991), Klevorick et al. (1994) and Blumenthal et al. (1986), who make analyses with parallels to this discussion. Also lending support to the use of the survey method is the fact that, among the more than 80 studies of the ATP, which is the American counterpart to Korea's CoE and ITRC programmes, eleven are based on survey methods (Ruegg and Feller 2003).

As respondents of this survey are limited to directors of research centres and managers of projects that have received public funds for research on the condition that cross-sector collaboration occurs, sample selection bias has been minimised. A maximum of 108 questionnaire responses is used in this study, and this makes for a 44 per cent overall response rate (see Appendix 1). In total, 1754 public–private R&D collaborations have been supervised by this sample of research directors and project leaders from 1997 to 2005 (999 and 755 projects for public and private sector respondents, respectively). Questionnaire responses are structured in several different ways, ranging from raw numbers, selections from zero to ten, selections from one to seven (Likert scale), and dummy variables.[4] The questionnaire was distributed and collected by the author, ministry-level officials, GRI-based directors, and government agency officials.

For example, to address the issue of sub-group delineations, research emphases from the KORTAI R&D dataset are based on a 7-point Likert scale. Looking first at the aggregate level, shown in Figure 1, applied research is most emphasised. Patenting follows at a close second, and the overall pattern is quite similar for both public and private sectors. Statistical tests, however, reveal variance between the indicated research emphases of the two components of the public research sector, the GRI and the university. In all cases except applied research emphasis, Kruskall-Wallis tests indicate that there are statistically significant differences between the research emphases of ETRI and universities. In the case of basic research emphasis and publications emphasis, the difference is simply too great to justify combining the two types of research entities under a singular heading. Figure 2 shows the separated public sector and the private sector, confirming expectations about the university focusing more on basic research and publications. This distinction shows that a 'public sector' classification must be approached with caution, as universities and GRIs are not homogeneous in Korea.[5]

Another method of analysing differences between sub-sector groups is through their collaborative tendencies, specifically the amount of collaboration done with the opposing sector. Tables 1 and 2 present the aggregate

4 A variable list is summarised in Appendix 2.

5 All private sector respondents are SMEs, given the nature of the public funding program calling for public-private R&D collaboration.

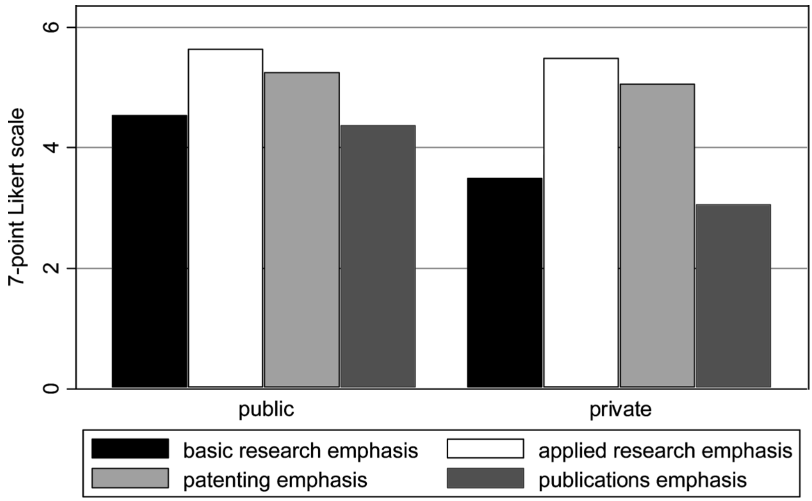

Figure 1: Average of research emphases by sector.
Source: KORTAI R&D dataset.

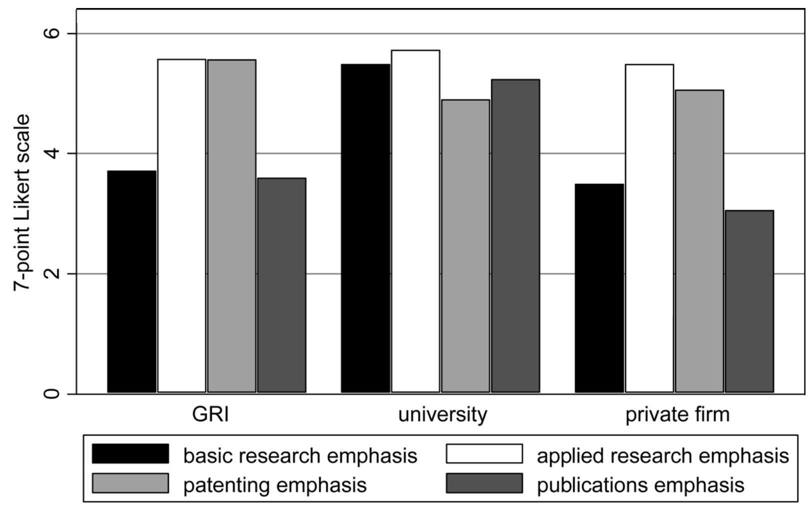

Figure 2: Average of research emphases by sector sub-groups.
Source: KORTAI R&D dataset.

and subsector amounts, respectively, of R&D collaboration with the opposite sector. The differences in these two tables reflect the biasedness inherent in any study, which does not differentiate between public and private sector sub-groupings. In Table 1, collaboration with the opposing sector ranges from almost 50 per cent for public sector respondents to just over one-third for private sector respondents. The KORTAI R&D dataset includes details about partnering tendencies at the subgroup level (for the

Source	Collaborator	Percentage
Public sector	Private sector	45.2
Private sector	Public sector	34.4

Table 1: Collaborative tendencies: aggregate level.

Source	Collaborator	Percentage
GRI	SME	29.7
	Large firm	37.0
University	SME	44.3
	Large firm	44.0
Private sector	GRI	33.3
	University	36.5

Table 2: Collaborative tendencies: sub-group level.

public sector), shown in Table 2. GRIs tend to collaborate significantly more with large firms than with SMEs, while universities work evenly with both SMEs and large firms. The private sector, on the other hand, collaborates slightly more with universities than GRIs.

Having established the need for sub-group sampling, we must now present the measures which capture new and pre-existing capital. Again, the Triple Helix has been claimed to generate new forms of capital, which is the logical result of having a new, dynamic research-based relationship with an entity from the opposing sector. The more precise issue to consider is whether new forms of capital created through Triple Helix-structured collaborations have a greater effect upon research output than pre-existing forms of capital. From the KORTAI R&D dataset, these relationships may be regarded as proxies for the capital arising through the Triple Helix structure.

New forms of capital generated through public–private R&D collaboration are measured by the percentage of collaboration done with partners from previous projects (*prevpart*). This variable is delineated by a discrete, time invariant value from 0 to 10, measuring percentage values from 0 to 100 in increments of 10. The richness of the KORTAI R&D dataset is reflected by seven different measurements of the reasons for such repartnering, all based on a 7-point Likert scale response ('7' being greatest): a lack of other qualified partners (*noother*); a stipulated funding condition (*fundstip*); a shared commitment (*sharecom*); a lack of tension (*lackten*); ease of communication (*easecom*); complementarity in knowledge (*compknow*); the presence of trust (*trust*) and expected commercialisation (*expcom*). Interviews between the author and project managers in Korea confirm that these reasons all have potential relevancy.[6] A conceptual framework outlining the possible interactions between these potential new forms of capital and research output is presented in Figure 3.

6 Summary statistics by sub-group are presented in Appendix 3(a).

7 Summary statistics for pre-existing capital measures are present in Appendix 3(b).

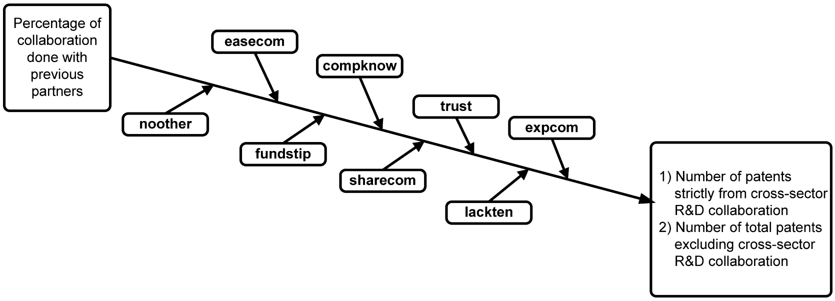

Figure 3: Tracing the effects of repartnering.

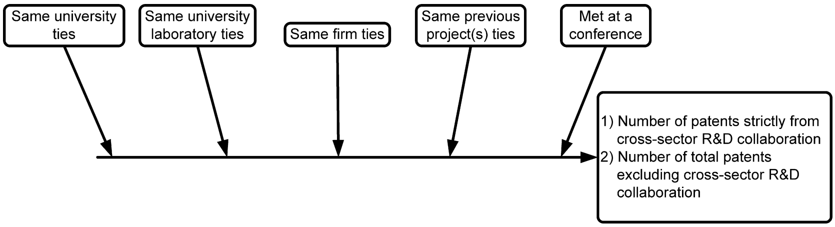

Figure 4: Tracing the effects of pre-existing ties.

The effects of new forms of capital will be held up in comparison to the effects of pre-existing forms of capital. This explanatory variable is also measured through the nature of public–private research relationships: personal ties (persties). Personal ties (persties) is a percentage of public–private R&D collaboration originating from pre-existing connections between the respondent and collaborators from the opposing sector. The variable is formulated by a number from 0 to 10, representing percentage values from 0 to 100 in increments of 10. The KORTAI R&D dataset also includes five dummy variables capturing the sources of the various forms of personal ties: university-based ties (sameuni), former university laboratory-based ties (sameunilab), former private firm-based ties (samefirm), ties through working on multiple previous projects (sameproj), and ties from meeting at a conference (sameconf).[7] Again, these five categories were selected as a result of the content of interviews held between the author and research directors in Korea.

A conceptual framework showing the interactions between pre-existing forms of capital and research output is shown in Figure 4. While Figures 3 and 4 show new and pre-existing forms of capital operating separately upon research output, they can also have simultaneous as well as interactive effects. These concerns will not be neglected in the subsequent analysis.

The dependent variable is R&D project output, measured by (1) the number of patents strictly from cross-sector R&D collaboration and (2) the

	1997	1998	1999	2000	2001	2002	2003	2004	2005
GRI	0.022	0.022	0.022	0.022	0.130	0.043	0.244	0.370	0.348
University	0.000	0.075	0.150	0.225	0.075	0.150	0.150	0.250	0.500
Firm	0.075	0.150	0.100	0.125	0.175	0.100	0.225	0.325	0.500

Table 3: Average number of patents through cross-sector R&D collaboration: by sub-sector.

	1997	1998	1999	2000	2001	2002	2003	2004	2005
GRI	1.00	1.848	1.957	2.239	2.435	3.087	3.978	6.609	8.304
University	0.175	0.450	0.725	0.675	1.000	1.125	1.350	1.350	1.750
Firm	0.025	0.075	0.050	0.200	0.231	0.615	0.745	0.692	1.462

Table 4: Average number of total patents excluding cross-sector R&D collaboration: by sub-sector.

number of total patents excluding cross-sector R&D collaboration. Consistency among results for these two dependent variables will confirm that there has been no major difference in the generation of both patent measurements. Use of both measures also illustrates the broader impact of new (or pre-existing) forms of capital upon R&D research results, not just those arising from public–private R&D collaboration. Tables 3 and 4 show the significant difference in the average number of patents per respondent (by sub-sector) via collaboration and excluding collaboration, respectively. This can effectively be construed as a Triple Helix – non-Triple Helix comparison. While these two figures show important changes over time, the subsequent empirical analysis will be static in nature (i.e., patent measurements will reflect data only for 2005, Figures 5 and 6), as all of our explanatory variables are time invariant.[8]

8 Questionnaire respondents were not expected to accurately recall the amount of previous participation or personal ties over time.

Empirical specification and results

Our first task is to compare the new forms of capital arising from the Triple Helix with pre-existing capital. This is done through a comparison of the *prevpart* and *persties* coefficients' separate effects upon research output. The first general model, thus, is

$$Y_{ij} = \mathrm{X}_{ik} + \varepsilon_i, \qquad (1)$$

where Y is the number of patents generated by respondent i in 2005, and j denotes the nature of the patent (either including or excluding collaborative projects). X represents the relationship-based capital discussed at length in the preceding sections. For respondent i, k is either new capital (*prevpart*) or pre-existing capital (*persties*). ε is the error terms for respondent i.

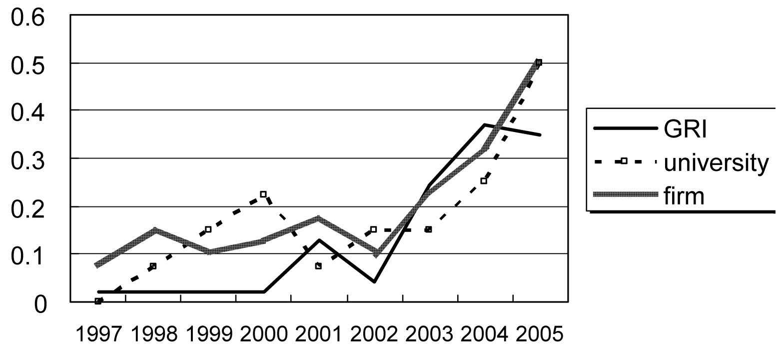

Figure 5: Patents through cross-sector collaboration (average).

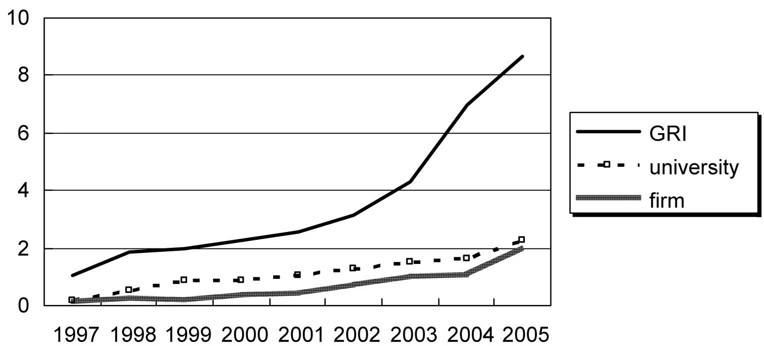

Figure 6: Total patents (average).

While the simple model in Eq. (1) considers either new or pre-existing relationship-based capital (given subscript *k*), Eq. (2) tests for their simultaneous effects, and Eq. (3) presents a test for their interactive effects:

$$Y_{ij} = X_{1i}\ X_{2i} + \varepsilon_i \tag{2}$$
$$Y_{ij} = X^{*}_{i} + \varepsilon_i. \tag{3}$$

The results of the two specifications offered in Eqs. (2) and (3) are intended to provide a deeper understanding of the possible effects of relationship-based capital, in contrast to the restrictive assumptions of Eq. (1).

There are a number of possible techniques to study the effects of new versus pre-existing forms of capital in a Triple Helix construct. Application of the ordinary least squares (OLS) statistical analysis is preferred, given the nature of our dependent and explanatory variables. When *j* is comprised strictly of collaborative patents, OLS results are presented by subsample in Table 5. Eq. (1) is shown in results (1) to (12), Eq. (2) is captured in results (13) to (15), and Eq. (3) is shown in results (19) to (21). When regression output is based on all patents excluding collaborative research work, Eq. (1) is shown in results (4) to (6) and (10) to (12), Eq. (2) in results (16) to (18), and Eq. (3) in results (22) to (24).

	Number of patents, strictly through collaboration			Number of patents, excluding collaboration		
	(1) GRI	(2) Univ.	(3) Firm+	(4) GRI	(5) Univ.	(6) Firm+
prevpart	0.054	1.16e-17	0.134**	0.255	0.635**	−.026
	(0.043)	(0.073)	(.054)	(0.461)	(0.310)	(0.129)
F-stat	1.62	0.00	6.18	0.30	4.18	0.04
R^2	0.035	0.000	0.140	0.007	0.099	0.001
N	46	40	40	46	40	39
	(7) GRI	(8) Univ.	(9) Firm+	(10) GRI	(11) Univ.	(12) Firm+
persties	−0.024	0.044	0.050	−0.124	0.323	0.147
	(0.045)	(0.062)	(0.058)	(0.484)	(0.277)	(0.126)
F-stat	0.27	0.49	0.75	0.07	1.36	1.36
R^2	0.006	0.013	0.020	0.002	0.035	0.036
N	46	40	40	46	40	39
	(13) GRI	(14) Univ.	(15) Firm+	(16) GRI	(17) Univ.	(18) firm+
prevpart	0.058	−0.024	0.130**	0.271	0.577*	−0.053
	(0.043)	(0.080)	(0.055)	(0.471)	(0.342)	(0.131)
persties	−0.030	0.052	0.030	−0.156	0.127	0.156
	(0.045)	(0.069)	(0.055)	(0.491)	(0.294)	(0.129)
F-stat	1.03	0.29	3.18	0.20	2.14	0.75
R^2	0.050	0.015	0.147	0.009	0.101	0.040
N	46	40	40	46	40	39
	(19) GRI	(20) Univ.	(21) Firm+	(22) GRI	(23) Univ.	(24) Firm+
prevpart persties*	0.007	0.008	0.022**	0.065	0.113***	0.018
	(.009)	(0.010)	(0.010)	(0.099)	(0.040)	(0.023)
F-stat	0.50	0.84	5.12	0.43	8.09	0.62
R^2	0.011	0.19	0.119	0.010	0.176	0.017
N	46	40	40	46	40	39

*, **, ***Statistically significant at the ten, five, and one per cent levels, respectively.

+Two private sector outliers were omitted.

Note: standard errors in parentheses.

Table 5: OLS results for new and pre-existing capital's effects upon output.

Our first and primary hypothesis is tested through a comparison of models (1) and (7), (2) and (8), and (3) and (9) in Table 5. In these cases, *j* is strictly comprised of collaborative patents. For the GRI and firm sub samples, the coefficients of the new forms of capital (*prevpart*) are greater than pre-existing forms of capital, while the firm case is statistically significant (model [3]). For the university sub-sample, a comparison of models (2) and (8) shows pre-existing forms of capital to have much greater predictability upon research output, although neither set of results are statistically significant.

These results confirm the need for sub-group delineation but, more importantly, show that new forms of capital do have an impact for GRIs and firms. When examining the simultaneous effects of new and pre-existing forms of capital upon research output, shown in models (13), (14), and (15), the picture is not much different. In terms of model validity and goodness-of-fit, the simultaneous analysis does have more predictive power, however, especially for the university sub-sample (model [14]). The test for the interactive effects of both types of capital – models (19), (20), and (21) – shows little in terms of the GRI sub-sample. There is a positive and significant effect for the firm sub-sample, evidencing the synergistic importance of both capital types. Most importantly, the interactive term, X^{*}_{i}, has the greatest significance for the university sub-sample, relative to the previous model specifications.

Turning now to those results which exclude collaborative patents as a dependent variable, horizontal comparisons are made. The benefit of the three right-hand side estimations in Table 5 is evident when making comparisons between each sub-group. This is an effective test for the effects within Triple Helix (the three left-hand side columns) and non-Triple Helix (the three right-hand side columns) environments.

A comparison of the sole effects of new forms of capital upon non-collaborative patents show the greatest difference for the university sub-sample (output [5]). Indeed, while the effects of new forms of capital are negligible in the Triple Helix structure, they are positive and significant for the university sub-group when patents exclude collaboration-based projects. One possible explanation for this phenomenon is the more extensive patenting done by university-based researchers after collaborative projects are completed, evidencing spillover effects of collaboration in the Triple Helix construct.

Personal ties have a much greater impact for universities and firms when the dependent variable excludes collaborative patents. Indeed, for every ten per cent increase in the amount of *persties*, university-based (non-collaborative) patents increase by approximately one-third. A similar impact is shown when both explanatory variables are included simultaneously (model [17]) and interactively (model [23]). The university sub-sample is clearly benefiting significantly more from both new and pre-existing capital when the analysis is based on the non-collaborative patent output.

The richness of the KORTAI R&D dataset allows us to examine details of relationship-based capital even further. With reference to Figures 3 and 4, the sources of new and pre-existing capital provide enable us to understand how and why each sub-group in Korea is repartnering or utilising personal ties with collaborators. Rather than base this examination on the summary statistics for the various sources of repartnering and personal ties, presented in Appendices 3(a) and 3(b), weights are assigned. That is, *prevpart* is weighted by each reason for repartnering to indicate the precise amount of impact: (*prevparti* × Z_{ni}), where Z_n is the *n*th reason for repartnering for respondent *i*. If a reason is strong but repartnering in weak, the reason has less importance. The rankings of these weighted reasons are presented in Table 6.

Rank	GRI	University	Firm
1	*trust* 27.91 (14.29)	*trust* 27.42 (16.49)	*trust* 28.41 (14.54)
2	*expcom* 26.35 (14.56)	*easecom* 24.36 (15.87)	*expcom* 26.04 (14.36)
3	*noother* 25.32 (13.87)	*compknow* 24.00 (15.21)	*compknow* 25.17 (13.91)
4	*compknow* 25.26 (13.00)	*expcom* 22.19 (13.28)	*easecom* 24.45 (13.46)
5	*easecom* 24.47 (12.35)	*noother* 21.14 (13.32)	*noother* 21.69 (11.71)
6	*fundstip* 21.88 (12.69)	*fundstip* 20.69 (14.00)	*sharecom* 21.66 (12.65)
7	*sharecom* 22.15 (12.97)	*sharecom* 19.83 (14.33)	*fundstip* 21.17 (13.01)
8	*lackten* 19.56 (11.37)	*lackten* 18.42 (12.82)	*lackten* 19.37 (12.80)

Table 6: Rankings of weighted reasons for repartnering.

Consistent results across all three sub-samples include the dominance of *trust*, and the relative unimportance of *fundstip*, *sharecom* and *lackten*. The low ranking of *fundstip* is an indicator that other forces are at work beyond public funding which create the impetus for re-partnership. For the GRI subsector, however, *expcom* is high on the list and has a mean value on par with that of the firm sample. This is consistent with the nature of the GRI's research emphases, presented in Figure 2. A final differentiation between GRIs and the university/firm sub-samples is a high ranking of *noother*. With a score approximately four points higher than the other two groups, GRIs place considerably more import on the fact that they have limited options in terms of re-partnerships.

A similar ranking system is also constructed for the nature of personal ties, although the dichotomous nature of the variables prevents a similarly scaled measurement. The Likert scale response for *persties* is weighted with each dummy variable (i.e., [*persties* × *sameuni*], [*presties* × *sameunilab*], etc.), generating the mean values for each relevant group, which are then ranked. What is most notable among these results, presented in Table 7, is the consistent, high ranking of *sameproj* for all groups. This source of personal ties corresponds with repartnering, lending considerable support for the 'new capital' hypothesis of Etzkowitz (2003). This category could not be omitted from the questionnaire for fear that it would create an omitted variable bias when conducting an analysis such as this. As well, the possibility that *persties* is an identical reflection of *prevpart* is not likely, given the considerable amount of personal ties arising from pre-existing relationships.

Rank	GRI	University	Firm
1	*sameproj* 1.96 (2.38)	*sameproj* 2.25 (2.81)	*sameproj* 2.08 (2.80)
2	*sameconf* 1.26 (2.23)	*sameconf* 1.70 (2.78)	*sameconf* 1.20 (2.26)
3	*sameunilab* 1.09 (2.03)	*samuni* 1.18 (2.46)	*sameuni* 0.88 (1.99)
4	*sameuni* 0.39 (1.37)	*samefirm* 0.85 (2.19)	*sameunilab* 0.48 (1.65)
5	*samefirm* 0.33 (1.33)	*sameunilab* 0.85 (2.39)	*samefirm* 0.18 (0.96)

Table 7: Rankings of weighted source of personal ties.

Conclusion

Theoretical and methodological contributions have been offered here in an attempt to bolster an understanding of the Triple Helix paradigm in Korea. This discussion has confirmed earlier claims which detail the benefits of the Triple Helix structure, particularly the increase of new forms of capital (Etzkowitz 2003). There are a number of qualifiers included here, however, which make it clear that caution must be exercised when breaking down the components of the paradigm on a number of levels. In this regard, this discussion promotes vigorous analysis of the Triple Helix, particularly in emerging, technology-emphasising countries such as Korea.

The evidence provided in this discussion supports the 'new capital' hypothesis of Etzkowitz (2003) with regard to the Triple Helix structure. Two different dependent variables are applied to compare the effects of this new, relationship-based capital upon the Triple Helix and alternative methods of R&D. Results are not consistent across sub-groups. In the context of the Triple Helix structure, new capital has a particular effect upon research output for the private firm sample and, to a lesser degree, for the GRI sub-sample. Pre-existing forms of capital do have an impact for the private sample, but only when such capital is interacted with new forms of capital. Ultimately, firm-based results are the best predictor of Etzkowitz's (2003) results.

Comparing instances of Triple Helix-based output with alternative forms of R&D output shows that the former can generate new forms of capital which are not immediately productive. Respondents utilise this new capital for other, non-collaborative projects, indicating spillover effects. This is the case for the university sub-sample in Korea. We conclude that this reflects the university sub-sample's focus on (basic and applied) research relative to patenting. After the collaborative project is complete, patenting is attempted.

From a policy perspective, it would appear prudent to facilitate those opportunities for public and private research entities to work together, such as the funding programmes included in the KORTAI R&D dataset. Based on the ranked and weighted reasons for repartnering, policies are not likely to directly affect the amount of new capital transferred.

However, by introducing the opportunity for cross-sector R&D collaboration, other reasons for repartnering become salient for the researcher. In this way, policies can have a direct effect for the initial partnership and an indirect but still important effect for repartnering. The results provided above are not grounds for cutting public funding, by any means.

A final word must also be said about the sociological underpinnings and ramifications of the Triple Helix paradigm. Although this issue has not been addressed at length here, it does not detract from the aforementioned attempts to empirically test for the effects of Triple Helix interactions upon R&D project output. It does, however, open up the possibility for future research on this subject matter. Indeed, with regard to East Asian countries such as Korea, distinct patterns of networking have oft been attributed to socio-cultural factors which are absent from 'western' models of networks (Hamilton and Biggart 1988). The strong-weak ties and formal-informal networks discourse summarised by Powell and Grodal (2005) is invariably important for the Korean case, especially as it has been determined that Korea has a relatively low level of trust in comparison to other developed nations, such as Japan and Germany (Kim 2000). Some claim that this causes low R&D productivity because of poorly coupled links between research entities (Kim 2000). The findings here state otherwise, calling for further investigation.

Appendices

	Sent	Received	Response rate
ETRI	99	49	0.49
CoE	66	24	0.36
ITRC	43	27	0.63
ITEP	118	42	0.36
Overall			*0.44*

Appendix 1: Questionnaire response rates.

Variable name	Variable description
persties	Percentage of PPRD collaboration originating from personal ties (Data points are from zero to ten, representing percentage values from zero to one hundred)
sameuni	Personal ties based on university ties dummy variable
sameunilab	Personal ties based on former university laboratory ties dummy variable
samefirm	Personal ties based on former private firm ties dummy variable
sameproj	Personal ties based on multiple previous projects dummy variable
sameconf	Personal ties based on meeting at a conference dummy variable
prevpart	Percentage of PPRD collaboration done with partners from previous projects (Data points are from zero to ten, representing percentage values from zero to one hundred)
noother	Repartnering affected by a lack of other qualified partners (seven-point Likert scale response, seven being greatest)
fundstip	Repartnering affected by funding stipulation (seven-point Likert scale response, seven being greatest)
sharecom	Repartnering affected by a shared commitment (seven-point Likert scale response, seven being greatest)
lackten	Repartnering affected by a lack of tension (seven-point Likert scale response, seven being greatest)
easecom	Repartnering affected by ease of communication (seven-point Likert scale response, seven being greatest)
compknow	Repartnering affected by complementarity in knowledge (seven-point Likert scale response, seven being greatest)
trust	Repartnering affected by presence of trust (seven-point Likert scale response, seven being greatest)
expcom	Repartnering affected by expected commercialisation (seven-point Likert scale response, seven being greatest)

Appendix 2: Variable list.

	GRI		University		Firm	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
prevpart	3.67	2.65	4.35	2.42	3.63	2.68
noother	5.38	1.10	4.61	1.63	4.52	1.33
fundstip	4.65	1.15	4.50	1.63	4.43	1.72
sharecom	4.74	1.33	4.31	1.75	4.52	1.45
lackten	4.26	1.33	3.92	1.30	3.85	1.46
easecom	5.32	0.77	5.11	1.51	5.10	1.29
compknow	5.47	0.86	5.10	1.51	5.24	1.30
trust	5.97	0.76	5.92	1.08	5.90	0.86
expcom	5.56	1.08	4.86	1.27	5.32	1.22

Source: KORTAI R&D dataset.
Notes: S.D.: standard deviation. Variables are measured along 7-point Likert scale.

Appendix 3(a): Descriptive statistics for "New Capital" variables.

	GRI		University		Firm	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
persties	2.89	2.54	4.08	2.81	3.25	2.68
sameuni	0.11	0.31	0.23	0.42	0.23	0.42
sameunilab	0.28	0.46	0.13	0.33	0.10	0.30
samefirm	0.09	0.28	0.15	0.36	0.05	0.22
sameproj	0.52	0.51	0.45	0.50	0.45	0.50
sameconf	0.28	0.46	0.33	0.47	0.28	0.45

Source: KORTAI R&D dataset.

Notes: S.D.: standard deviation. Variables are measured along 7-point Likert scale.

Appendix 3(b): Descriptive statistics for "Pre-existing Capital" variables.

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